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6. ANALYSIS OF EFFECTS

6.1 EFFECTS ON ESA LISTED FISH SPECIES AND THEIR HABITAT

The potential for adverse effects on ESA listed fish and critical habitat varies depending on site specific features such as physical setting, individual project operations and activities, other anthropogenic influences, and species and life stages of listed fish that may be present. Figures 4-1 through 4-4 shows the general times that specific life history stages are present in the Willamette system. The large geographic scale of the entire Willamette Project, plus the time passed since project implementation, also influence the nature and degree to which direct and indirect effects may be incurred. This analysis therefore evaluates effects of individual projects and of the system as a whole, and when appropriate uses historic effects as a guide for identifying likely present effects. Effects on ESA-listed fish and critical habitat are addressed in ten distinct sections below that reflect different types of effects. The first nine involve effects that are likely to occur above Willamette Falls; the tenth is for below the falls.

The distinction is made in this chapter between potential effects and likely effects. All potential effects relevant to the Willamette Project and Willamette River basin are identified within each section irrespective of whether they are a past, current, or future concern. The extent and likelihood that specific actions will cause adverse effects is then discussed. The possibility that an effect exists does not imply that it is likely to happen, nor that it is likely to be sufficiently adverse. This BA considers the likelihoods that an activity responsible for an effect actually occurs, that a mechanism or pathway exists whereby the effect can be manifest, and that the effect is sufficient to result in take of individual fish or result in adverse modification of their habitat. Adverse effects to listed fish or critical habitat are identified that are most likely to be observed. In most, if not all cases, it is difficult to determine distinct statistical probabilities for purposes of quantifying the likelihood of an effect. At best, available information can be reviewed and evaluated to determine only the approximate order of magnitude of the effect; e.g., low, moderate, high. Analyses must then involve some judgement to determine whether the corresponding effect is likely to be adverse. The analysis becomes increasingly difficult with scale of the activity. Because the Willamette Project influences a large region in a large number of ways, it is useful to identify all potential effects, rule out those that are unlikely, and identify those most likely to adversely affect listed species and critical habitat. Remaining effects are assumed to be superposed by these first-order effects and are less likely to influence recovery significantly.

6.1.1 Effects of Changes in Downstream Hydrography and Water Quantity

The Willamette Project has resulted in significant changes to the water balance in the mainstem rivers downstream of each dam facility. These changes have various direct and indirect effects on the listed species. Most of the potential effects identified in section 6.1.1.1 are manifest by one or more projects, but have not been quantified with respect to numbers of fish, or quantity and quality of habitat influenced. This section evaluates hydrologic and hydrographic effects on listed fish using as much supporting information as possible. Appendix F contains plots of mean monthly flows and flood frequency characteristics before and after dam construction, below and above Willamette Project facilities. The plots were used to evaluate flow-related effects of the projects. In general, dam construction resulted in higher summer and fall flows, and lower winter and spring flows downstream (Appendix F).

The flow records from gages located above the dams were also split in Appendix F to identify the possible influence of climatic variation on before- and after- hydrograph comparisons made using data from gages located downstream of the dams. More detailed modeling and hydrologic studies would be needed to conclude any effect of climate, since the pre-dam records are generally too short; climatic contribution to changes in hydrography relative to the influence of dam construction can be evaluated only in a rudimentary sense using the plots. However, the plots suggest that some natural variation could have influenced before- and after- comparisons made below dams throughout most of the Willamette River basin during the late fall and early winter months, particularly in December and January. Nevertheless, the dams must also have had a strong effect on the average hydrograph during that part of the year because of their capacity to attenuate flood flows.

Changes to the hydrograph may have long term effects on the listed species that continue to evolve through influences on geomorphology and habitat maintenance that are addressed in section 6.1.5. Influences on water quality and temperature are shorter-term in nature and are addressed in section 6.1.2. This section evaluates effects that are related specifically to the hydrograph, including the influence of instream flows on physical habitat availability below the dams, smolt travel time, and effects of flow fluctuations associated with seasonal water management and daily hydropower operations. General effects common to all projects are identified first, followed by subbasin and project-specific effects.

6.1.1.1 Potential Effects

Dam construction is generally associated with significant changes to runoff hydrographs downstream of the associated impoundment. Effects can include changes in discharge magnitude, duration, and frequency that depends on site, hydrology, watershed, and operational characteristics. The changes can have either adverse or beneficial effects on the aquatic ecosystem depending on time of year, the species, and life stages present, and the nature of the flow releases.

Impoundments act as a low-pass filter during storm and snowmelt runoff. Upstream hydrographs during extreme events are attenuated downstream of the dam because of temporary storage effects of the reservoir. Depending on the amount of storage available and how the dam is operated, impoundments can reduce the magnitude of the mean annual flood downstream by 50 percent or more (Petts 1984). The amount of storage also influences whether or not an extreme flood event is attenuated significantly downstream. Reduced flood peaks can have a number of effects on the aquatic ecosystem. Catastrophic flooding may be reduced, resulting in smaller disturbance to the channel and fish habitat. Under the right circumstances, this may result in increased production of salmonids and other fish species because their populations or their food experience fewer large scale "resets." However, if flood magnitudes are reduced sufficiently that channel maintenance processes are interrupted or prevented, fish and invertebrate habitat may degrade through siltation and imbrication of substrate, or by vegetation encroachment.

Dams typically result in reduced annual (i.e., seasonal) flow variability. Flows in the Willamette system are typically reduced from historic during the peak runoff season and increased over historic during the low flow season, depending on operations and water uses downstream. Reduced average flows during the peak runoff season may influence downstream migration patterns of smolts that rely on high flows for initiating and facilitating movement. Downstream passage times may be increased because of reduced flow rates. Adults migrating upstream to spawn may be delayed because they are waiting for a freshet signal to begin or resume migration, with resulting increased susceptibility to disease and expenditure of energy reserves.

Increased average flows during the low flow season tend to result in beneficial effects because of positive effects on water temperature (may be reduced over historic) and dissolved oxygen levels (may offset other biological and chemical oxygen demands). Such flows also afford more physical habitat space and therefore may result in increased carrying capacity during the summer, fall, and winter. In certain instances, reduced annual flow variability could be associated with large resident salmonid populations because of habitat stability for fish and their food.

Hydroelectric dams used for power peaking ("load following") release fluctuating flows that can result in stranding and trapping of fish, limit availability of spawning gravels, and influence production of benthic invertebrates, an important fish food source. Stranding is usually restricted to fish that are smaller than a specific length, and occurs for a specific set of conditions involving gradual bed slopes and large substrate. For salmonids, fry 50 mm in length and smaller have been shown to be most vulnerable to stranding (Hunter 1992). Fingerlings, smolts and adults may be vulnerable to stranding in other seasons, but at flow change ("downramping") rates much greater than those resulting in the stranding of fry. Trapping, in which fish located over small topographic depressions become isolated (and possibly stranded later) as the depression becomes disconnected from the main flow, is influenced more by starting and ending flow magnitudes than it is by downramping rates, because it is related to water surface elevation and bed microtopography (Hunter 1992). Spawning habitat may be limited if its location is restricted primarily to portions of the channel that are alternately inundated and exposed through frequent flow fluctuations. Benthic invertebrate production may also be limited within the zone experiencing repeated flow fluctuations, and can exhibit shifts in community structure in some cases (DosSantos et al. 1988). Re-regulation dams reduce or eliminate adverse effects of power peaking by storing the high flows and releasing water more steadily; the affected reach is then limited to the length of river between the power-producing (upper) and re-regulating (lower) dams.

Dams can facilitate water withdrawals during the summer and fall low flow period, which can be linked to potential impacts to critical habitat in terms of water temperature, water quality, and habitat availability if flows below the dam are reduced from historic rates. Reduced summer stream flows could result in several impacts to critical habitat and ESA-listed fish. The most important include: the reduction and elimination of physical living space for resident and holding anadromous adults prior to spawning; the reduction and elimination of spawning and incubation habitat; dewatering of redds leading to desiccation of eggs and alevins; the reduction and elimination of rearing habitat; and increased water temperatures during warm months (Petts 1984; Marcus et al. 1990). Water withdrawal during low flow periods also reduces the dilution capacity of streams with respect to pollutants. Reduced dilution capacity could be harmful to listed fish depending on the specific water quality parameters (see Section 6.1.2).

Impoundments also lead to increased water loss through evaporation, making less water available for release downstream. Reductions in average annual runoff of 20 percent or more have been reported (Petts 1984). The magnitude of the effect is greater in more arid climates. Between-year storage can reduce the magnitude of the effect to a limited extent by redistributing water from wetter years to release in dryer years, except when there is a prolonged drought. Flood control projects generally do not have significant between-year storage capacity and their evaporative losses influence that year's runoff only.

6.1.1.2 Effects on Instream Flows and Physical Habitat

Table 6-1 lists instream flow water rights on file at the OWRD for rivers downstream of Willamette Project facilities. Instream flow water rights are held in trust by the OWRD (Root 1995). The majority of instream water rights have priority dates from the early 1960s and are thus junior to numerous older water rights (OWRD data). The greatest period of concern for instream flow protection is during the summer low flow period when senior water rights are exercised the most (water stored to provide for those rights is a small fraction of the volume of water released), and water is in greatest demand by multiple users. Current summer instream flows usually exceed OWRD requirements by more than a factor of two (see graphs in Appendix F). Summer stream flows in the McKenzie River are relatively high compared to the other subbasins in part because of the presence of extensive lava fields in the headwaters (Hutchison et al. 1966b). In general, irrigation water needs are low relative to the amount of water released from the Willamette Project dams.

The RCC develops an annual summer flow augmentation plan and conducts a coordination meeting with various federal, state, and local agencies. State agencies include the OWRD, ODFW, Oregon State Marine Board (OSMB), and ODEQ. The coordination process attempts to balance the state's water management objectives for the Willamette Project with USACE policy and project authorizations.

Current instream flow requirements can be compared with flows recommended in USACE (1982) as being the minimum needed for good upstream passage (Table 6-2), spawning (Table 6-3), incubation (Table 6-4), and rearing (Table 6-5) conditions, and the maximum needed to protect redds (Table 6-6) in stream reaches downstream of USACE dams; no flows were specified for the Long Tom River because of non-use by anadromous salmonids. The flows identified in Tables 6-2 through Table 6-6 reflect in part minimum flow recommendations reported by Hutchison et al. (1966b) are based on a number of biological and site-specific factors, and may not reflect natural flow availability. They are generally much larger than current minimum instream flows required by OWRD (Table 6-1), except in the Coast Fork Willamette River subbasin where they are similar in magnitude.

Table 6-1. Minimum instream flow requirements downstream of Willamette Project dams, Oregon (Source: WRIS files, OWRD 1999).

Stream / Location	Priority Date	Flow (cfs)	Period	Purpose
Willamette River				
Above Willamette Falls to Mouth	4/20/71	1500	all year	Supporting aquatic life
At USGS gage no. 14-1980 at Wilsonville	6/22/64	1500	all year	Supporting aquatic life
At USGS gage no. 14-1910 at Salem	6/22/64	1300	all year	Supporting aquatic life
At USGS gage no. 14-1740 at Albany	6/22/64	1750	all year	Supporting aquatic life
Between Coast Fork and McKenzie R	11/3/83	2000 2500	Jun 1 - Oct 31 Nov 1 - May 31	Supporting aquatic life and minimizing pollution
Santiam River				
Mouth to RM 1.0	6/22/64	320	all year	Supporting aquatic life
At USGS gage no. 14-1890 at Jefferson	6/22/64	330	all year	Supporting aquatic life
North Santiam River				
At USGS gage no. 14-1841 Near Jefferson	6/22/64	430	all year	Supporting aquatic life
At USGS gage no. 14-1830 at Mehama	6/22/64	580	all year	Supporting aquatic life
At USGS gage no. 14-1815 at Niagara	6/22/64	500	all year	Supporting aquatic life
At USGS gage no. 14-1780 near Boulder Creek	6/22/64	345	all year	Supporting aquatic life
South Santiam River				
At USGS gage no. 14-1875 at Waterloo	6/22/64	170	all year	Supporting aquatic life
At USGS gage no. 14-1850 below Cascadia	6/22/64	50	all year	Supporting aquatic life
McKenzie River				
At I5 crossing	6/22/64 [1]	1025	all year	Supporting aquatic life
At USGS gage no. 14-1625 near Vida	6/22/64 [1]	1400	all year	Supporting aquatic life
South Fork McKenzie River				
Mouth to RM 1.0	6/22/64 [1]	200	all year	Supporting aquatic life
Blue River				
Mouth to RM 1.0	6/22/64 [1]	30	all year	Supporting aquatic life
Fall Creek				
Mouth to RM 1.0	6/22/64 [1]	40	all year	Supporting aquatic life
Middle Fork Willamette River				
Coast Fork confluence to 1 mile upstream	6/22/64 [1]	640	all year	Supporting aquatic life
North Fork confluence to 1 mile upstream	6/22/64 [1]	285	all year	Supporting aquatic life
Coast Fork Willamette River				
Middle Fork confluence to 1 mile upstream	6/22/64 [1]	40	all year	Supporting aquatic life
Row River confluence to 1 mile upstream	6/22/64 [1]	15	all year	Supporting aquatic life
Cottage Grove Dam to Row River	1/16/97	125	Nov 16 - Mar 31	Anadromous and resident fish life
Row River to mouth	1/16/97	200	Nov 16 - Mar 31	Anadromous and resident fish life

Table 6-1. Minimum instream flow requirements downstream of Willamette Project dams, Oregon (Source: WRIS files, OWRD 1999).

Stream / Location	Priority Date	Flow (cfs)	Period	Purpose
Row River				
Coast Fork confluence to 1 mile upstream	6/22/64 [1]	40	all year	Supporting aquatic life
Dorena Dam to mouth	1/16/97	175	Nov 16 - Apr 30	Anadromous and resident fish life
Long Tom River				
At USGS gage no. 14-1700 at Monroe	6/22/64	(not specified)	(all year)	Obtaining the highest and best use of waters from storage

[1] also listed for 5/24/62

Table 6-2. Flows recommended for good upstream passage of salmon and steelhead for rivers that are regulated by Willamette Project dams, Oregon (USACE 1982).

Location	Flow (cfs)	Time Period	Species	Regulation Point
Middle Fork Willamette River below Dexter	900	Apr 15-Jun 30	Spring Chinook	Dexter Dam
	700	Mar 1-Apr 15	Steelhead	
South Santiam River below Foster	900	Apr 15-Jun 30	Spring Chinook	Waterloo
	900	Sep 1-Sep 30	Fall Chinook	
	700	Mar 1-Apr 15	Steelhead	
		Jun 30-Oct 1		
North Santiam River below Big Cliff Reservoir	900	Apr 15-Jun 30	Spring Chinook	Big Cliff Dam
	900	Sep 1-Sep 30	Fall Chinook	
	700	Mar 1-Apr 15	Steelhead	
Middle Santiam River [1] below Green Peter	50	Mar 1-Jun 30	Spring Chinook	Green Peter
			Steelhead	
Fall Creek [2] below Fall Creek Dam	170	Apr 15-Jun 30	Spring Chinook	Fall Creek Dam
	75	Mar 1-Apr 15	Steelhead	
Coast Fork Willamette mouth to Row River	200	Oct 15-Dec 1	Fall Chinook	Just below Row River
	175	Jan 1-May 15	Steelhead	
Row River below Dorena Dam	175	Oct 15-Dec 1	Fall Chinook	Dorena Dam
	150	Jan 1-May 15	Steelhead	

[1] It was recommended that flow should be reduced to 50 cfs for part of each afternoon period during fish passage season to bring fish into the fish ladder.

[2] Experience at Fall Creek in 1977 and 1978 showed that 150 cfs is sufficient to provide adult transport, and that this flow should not be interrupted frequently with lower flows. Considerable straying of marked fish was noted to have occurred when a week flow schedule of three days at 150 cfs and four days at 50 cfs was followed.

Table 6-3. Minimum spawning flows recommended below each reservoir for rivers that are regulated by Willamette Project dams, Oregon (USACE 1982).

Location	Flow (cfs)	Time Period	Species	Regulation Point
Middle Fork Willamette River below Dexter	1200	Sep 10-Oct 10 Mar 1-Jun 1	Spring Chinook Steelhead	Dexter Dam
South Santiam River below Foster	1000	Sep 10-Oct 10 Mar 1-Jun 1	Spring Chinook Steelhead	Waterloo
North Santiam River below Big Cliff	1000	Sep 10-Oct 10 Mar 1-Jun 1	Spring Chinook Steelhead	Big Cliff Dam
Fall Creek below Fall Creek	150	Sep 10-Oct 10 Mar 1-Jun 1	Spring Chinook Steelhead	Fall Creek Dam
Row River below Dorena Dam	200	Oct 15-Dec 10 Mar 1-Jun 1	Fall Chinook Steelhead	Dorena Dam
Coast Fork Willamette River mouth to Row River	250	Oct 15-Dec 10 Mar 1-Jun 1	Fall Chinook Steelhead	Just below Row River
South Fork McKenzie	400	Sep 10-Oct 10	Spring Chinook	Cougar Dam
McKenzie River Blue River to mouth	2500	Sep 10-Oct 10	Spring Chinook	Vida
Willamette River McKenzie to Corvallis	6500	Sep 10-Oct 10	Fall Chinook	Harrisburg

Table 6-4. Minimum incubation flows recommended below each reservoir for rivers that are regulated by Willamette Project dams, Oregon (USACE 1982).

Location	Flow (cfs)	Time Period	Species	Regulation Point
Middle Fork Willamette River below Dexter	One foot lower than flow level at spawning time	Oct 1-Mar 15 Apr 1-Jun 15	Spring Chinook Steelhead	Jasper
South Santiam River below Foster Dam	800 cfs One foot lower than flow level at peak spawning	Oct 1-Mar 15 Apr 1-Jul 1	Spring Chinook Steelhead	Waterloo
North Santiam River below Big Cliff Dam	1000 cfs One foot lower than flow level at peak spawning	Oct 1-Mar 15 Apr 1-Jul 1	Spring Chinook Steelhead	Big Cliff Mehama
Fall Creek below Fall Creek Dam	150 cfs 75 cfs	Oct 1-Mar 15 Apr 1-Jul 1	Spring Chinook Steelhead	Fall Creek Dam
Row River below Dorena Dam	150 cfs	Nov 15-Apr 1 Apr 1-Jun 15	Fall Chinook Steelhead	Dorena Dam
Coast Fork Willamette River mouth to Row River	250 cfs	Nov 15-Apr 1 Apr 1-Jun 15	Fall Chinook Steelhead	Goshen
South Fork McKenzie River Below Cougar	400 cfs	Oct 1-Mar 15	Spring Chinook	Cougar Dam
McKenzie River Blue River to mouth	2000 cfs	Oct 1-Mar 15	Spring Chinook	Vida
Willamette River	One foot lower than flow level at peak spawning	Oct 1-Mar 15	Fall Chinook	Harrisburg

Table 6-5. Minimum flows recommended for salmonid rearing for rivers that are regulated by Willamette Project dams, Oregon (USACE 1982).

Location	Flow (cfs)	Time Period	Regulation Point
Middle Fork Willamette River below Dexter Dam	1600 800	Jun 1-Oct 30 Nov 1-Jun 1	Dexter Dam
Middle Fork Willamette River from Hills Creek Dam to Lookout Point Reservoir	285	Throughout year	Hills Creek Dam
South Santiam River below Foster Dam	800 600	Jun 1-Oct 30 Nov 1-May 30	Waterloo
North Santiam River below Big Cliff Dam	1000 800	Jun 1-Oct 30 Nov 1-May 30	Big Cliff Dam
Fall Creek below Fall Creek Reservoir	150 50	Jun 1-Oct 30 Nov 1-May 30	Fall Creek Dam
Row River below Dorena Dam	300 100	Jun 15-Oct 30 Nov 1-Jun 15	Dorena Dam
Coast Fork Willamette River mouth to Row River	350 200	Jun 15-Oct 30 Nov 1-Jun 15	Goshen
South Fork McKenzie River below Cougar Dam	250	Throughout year	Cougar Dam

Table 6-6. Maximum flow recommended during spawning to keep redds in water during incubation for rivers that are regulated by Willamette Project dams, Oregon (USACE 1982).

Location	Flow (cfs)	Time Period	Species	Regulation Point
Middle Fork Willamette River [1] below Dexter Dam				
South Santiam River below Foster Reservoir	2000	Sep 10-Oct 10	Fall Chinook	Waterloo
North Santiam River below Big Cliff	2400	Sep 10-Oct 10	Spring Chinook	Big Cliff Dam
Fall Creek [1] below Fall Creek Dam				
Row River below Dorena Dam	690	Oct 15-Dec 10	Fall Chinook	Dorena Dam
Coast Fork Willamette River mouth to Row River	850	Oct 15-Dec 10	Fall Chinook	Goshen
South Fork McKenzie River below Cougar Dam	1100	Sep 10-Oct 10	Spring Chinook	Cougar Dam
McKenzie River from Blue River to mouth	3700	Sep 10-Oct 10	Spring Chinook	Vida
Willamette River McKenzie to Corvallis	7500	Sep 10-Oct 10	Fall Chinook	Harrisburg

[1] Because of large fluctuations of stream levels under normal operations of the reservoirs, it was considered impractical at the time to recommend maximum spawning flows below these reservoirs.

The flows listed in Tables 6-2 through 6-6 likely provide a better measure of the effect that dam releases have on habitat elements critical to listed salmonid species than minimum instream flow water rights, because they were developed according to specific biological criteria and the professional judgement of fisheries biologists familiar with the system. Flow recommendations made for fall chinook salmon are assumed to be applicable to spring chinook salmon at times when they would be present; flow recommendations have not been made specifically on behalf of Oregon chub or resident salmonids.

The flows in Tables 6-2 through 6-6 were compared against with-dam flow duration statistics to evaluate the percent of time that they are likely to be exceeded. A high frequency of exceedance of the recommended flows at gages below the dam should imply a small to negligible effect of dam operations on instream flows and fish habitat downstream. Since specific studies could not be found regarding the effects of instream flows on fish in the Willamette system, it is assumed here that adverse effects could potentially occur when the mean daily discharge is exceeded less than 50 percent of the time in a given month. Table 6-7 lists selected flow duration statistics for gages located downstream of Willamette Project dams, computed from flows gaged after dam construction. The comparisons are summarized below:

Upstream passage flow recommendations listed in Table 6-2 are generally met more than 90 percent of the time below most projects, and more than 50 percent of the time below all projects (Moffatt et al. 1990); upstream passage therefore does not appear to be affected adversely by flow releases in general.

Spawning flow recommendations listed in Table 6-3 are generally met more than 80 percent of the time below most projects, and more than 70 percent of the time below all projects except Fall Creek (Moffatt et al. 1990); spawning habitat is therefore not likely to be affected adversely by released flow rates in general, with the possible exception of Fall Creek.

Incubation flow recommendations listed in Table 6-4 are lower than spawning flows and are thus met more frequently. With the possible exception of Fall Creek, there is no apparent adverse effect of flow releases on incubation habitat availability (excluding temperature effects addressed in Section 6.1.2).

Table 6-7. Selected monthly flow duration statistics measured at USGS gages located below Willamette Project dams, Oregon (Data from Moffatt et al. 1990).

		Monthly Exceedance Flows (cfs)								
		April			August [1]			September		
Dam	**Gage #**	**95%**	**80%**	**50%**	**95%**	**80%**	**50%**	**95%**	**80%**	**50%**
Detroit/Big Cliff	14181500	712	997	1230	863	994	1120	1010	1260	1980
Foster	14187500	961	1200	2240	484	614	739	628	863	1340
Blue River	14162200	14	46	178	(Oct.) 17	(Oct.) 59	(Oct.) 190	50	57	199
Cougar	14159500	109	267	327	318	410	676	459	752	700
Fall Creek	14151000	210	349	604	29	38	48	27	33	41
Dexter/Lookout Point	14150000	609	1190	1290	1140	1480	1750	1270	1810	2890
Hills Creek	14145500	103	295	622	287	384	671	476	827	1320
Dorena	14155500	172	199	524	91	99	258	90	126	315
Cottage Grove	14153500	48	73	100	25	43	55	23	51	162
Fern Ridge	14169000	25	43	56	26	37	55	31	39	55

[1] - August Flows at Blue River much higher than natural; October flows listed instead

Rearing flow recommendations listed in Table 6-5 are generally met during the winter more than 90 to 95 percent of the time below all projects. During the summer, the flow recommendations are generally met more than 50 to 70 percent of the time, with the exception of Fall Creek and the Coast Fork Willamette River subbasins where flows are less than half the recommended rearing flow rate nearly half the time (Moffatt et al. 1990). However, current summer instream flows are greater than historic in all subbasins, implying improvements have occurred in summer habitat conditions for fish below Willamette Project facilities through increased habitat space and better water quality. Few, if any spring chinook salmon are found in the Coast Fork Willamette River subbasin, and habitat space is therefore unlikely to be limiting production there. Winter steelhead are not native to either the Coast Fork or Middle Fork Willamette river subbasins, which furthermore are not part of winter steelhead critical habitat.

Redd protection flow recommendations listed in Table 6-6 are generally met more than 50 percent of the time in the Coast Fork Willamette River subbasin, more than 90 percent of the time in the McKenzie River subbasin, and roughly 60 to 80 percent of the time in the Santiam River subbasin (Moffatt et al. 1990). In general, the dams have reduced the magnitude of flood peaks (see flood frequency plots in Appendix F) and thus provide improved redd protection over natural conditions.

The flow data and tables suggest that the Willamette Project generally does not adversely affect aquatic habitat during the summer or winter through the effects of reduced instream flow, with the possible exceptions noted.

6.1.1.3 Effects on Smolt Migration Initiation and Travel Time Below Dams

Recent work has pointed to the importance of the timing and duration of short-term flow changes to stimulating downstream migration of juvenile salmonids. Buettner and Brimmer (1996) determined that a 2-fold increase in flow was associated with an 8- to 12-fold increase in migration rate for hatchery chinook and 3.5- to 4.6-fold increase for wild chinook salmon, in the upper Snake River. Knapp et al. (1995) determined that pulsing water releases appeared to increase the effectiveness of initiating fish movement in the lower Umatilla River. Sustained fish movement was not positively correlated with sustained high flows. Demko (1996) determined that release of a pulse of stored water stimulated a substantial increase in juvenile chinook outmigration in the Stanislaus River, California. Increases in fish movement lasted only a few days following the release.

Similar studies have not been conducted in the Willamette River, and it is unknown whether this is an important influence on survival of juvenile downstream migrant salmonids. Schreck et al. (1994) noted that high water in 1993 seemed to flush fish from the system relatively quickly, but it is unclear whether this was because of increased water velocity decreasing travel time or because of a flow-related stimulus. Flows downstream of each dam are generally reduced and smoothed out during the spring compared to historic conditions (see Appendix F) as the reservoirs fill for summer low flow augmentation and recreation purposes. It is conceivable that naturally-produced juveniles adapted to a spring pulse, and that pulses occurring early in the spring season could have enabled fish to begin migrating downstream before water temperatures increased too much in the mainstem Willamette River. However, since springtime water temperatures below the Willamette Project dams are presently cooler than historic levels (see Section 6.1.2), it is more likely that any such effect would be masked currently by other influences on downstream migrant survival.

Specific effects of the Willamette Project on smolt travel time downstream of the dams are unknown. Water velocity, temperature, level of smolt development and time of year all influence juvenile migration speed, whereas the influence of turbidity is unclear (Giorgi et al. 1985; Beeman and Rondorf 1992; Berggren and Filardo 1993; Achord et al. 1994; Chapman et al. 1994; Buettner and Brimmer 1995; Skalski and Townsend 1999). Willamette River basin smolts migrating below USACE reservoirs in the spring may move slower than their historic counterparts because of reduced spring flows as the reservoirs fill to meet summer water demands (See rule curves in Appendix E and mean monthly flow statistics in Appendix F).

The effect of reduced water velocity in the spring can be evaluated to first order by assuming that travel time is inversely proportional to water velocity, which can be estimated by predicting channel cross-section area at different locations in the basin using the area-discharge relation of Laenen and Risley (1997) and then dividing it into the discharge. Table 6-8 shows the before- and after- Willamette Project estimates of mean velocity during March, April, and May, the peak downstream passage time for Upper Willamette chinook salmon and steelhead trout, at several locations throughout the basin. Mean monthly flows from Appendix F were used to generate the table. The table shows the absolute and percent change in mean water velocity according to the models of Laenen and Risley (1997). The table also shows a separate estimate of the percent change in velocity derived using Lee's (1995) estimate that mean water velocity in Willamette River and Calapooia River mainstems varies approximately with the 0.4 power of discharge in cubic feet per second. The two independent estimates are not substantially different.

Table 6-8. Estimated change in mean water velocity after dam construction in the Willamette River basin, calculated for average monthly flows.

		Using Model of Laenen and Risley (1997)						Using Equation of Lee (1995)		
		Change in Mean Velocity (miles/day)			% Change			% Change		
Stream/Location	Dam(s) Upstream [1]	March	April	May	March	April	May	March	April	May
Willamette River										
At Salem	All 13	-2.4	-4.4	-2.1	-3.4	-6.6	-3.5	-4.4	-8.4	-4.5
At Albany	FC,LPD,HC,CG,Do, FR,Co,BR	-3.8	-5.4	-3.9	-5.9	-8.9	-7.1	-7.0	-10.3	-8.1
At Harrisburg	FC,LPD,HC,CG,Do,Co,BR									
Middle Fork Willamette River										
Below Fall Creek	FC,LPD,HC	-10.6	-8.6	-4.7	-15.1	-13.4	-7.8	-16.7	-14.8	-8.6
Below North Fork	HC	-5.3	-6.1	-3.1	-8.8	-9.8	-5.2	-9.7	-10.8	-5.7
Coast Fork Willamette River										
Near Goshen	CG,Do	0.4	-0.6	-2.8	0.8	-1.4	-8.1	0.6	-1.0	-5.9
McKenzie River										
Near Vida	BR,Co (and Carmen)	-5.6	-11.8	-4.9	-7.1	-14.7	-6.3	-5.4	-11.1	-4.7
Santiam River										
At Jefferson	DBC,Fo,GP	-8.7	-11.6	-9.4	-12.2	-18.0	-15.9	-7.5	-10.8	-9.4
North Santiam River										
At Mehama	DBC	-8.7	-7.7	-14.2	-9.3	-8.0	-15.2	-10.9	-9.4	-17.7
South Santiam River										
At Waterloo	Fo,GP	-8.9	-11.6	-6.7	-15.5	-21.3	-14.6	-11.3	-15.4	-10.1

[1] Key: FL = Fall Creek; LPD = Lookout Point/Dexter; HC = Hills Creek; CG = Cottage Grove; Do = Dorena; FR = Fern Ridge; Co = Cougar; BR = Blue River; DBC = Detroit/Big Cliff; Fo = Foster; GP = Green Peter

Table 6-8 indicates that the effect of the Willamette Project on average travel time for smolts during the outmigration period is small. Estimated water velocities average on the order of 50 to 90 miles per day during the spring runoff period with the dams in place. Assuming that fish velocity is half the average channel velocity during downstream migration, it should take a smolt starting its migration below Dexter Dam only a few days to reach Willamette Falls. These numbers have been corroborated by Schreck et al. (1994) who determined that the majority of juvenile spring chinook salmon that they monitored migrated from Dexter Dam to Willamette Falls in four days. Similar results would be expected for other dams located approximately the same distance from the falls, including Cougar, Blue River, and Fall Creek dams. The change in water travel time caused by the Willamette Project dams is therefore likely to be negligible, and it is assumed that associated delays in migration are also negligible for juvenile salmonids beginning their migration below the dams.

Although not directly a function of flow, chinook salmon and winter steelhead smolts originating from natural spawning upstream of the reservoirs (including either presently from hatchery supplementation or in the future if reintroduced) are likely to be delayed as they migrate downstream through the reservoirs because of the reduction in water velocity. This could adversely affect survival because of increased susceptibility to predation, and changes in peak emigration timing could result in smolts traveling later in the season in the mainstem Willamette River when water quality becomes potentially more important. Active rearing in the reservoir could also slow down the rate of migration, or lead to residualization as may have occurred in Detroit and Cougar reservoirs. While part of their respective ESUs, hatchery-supplemented spring chinook and winter steelhead are not considered essential for recovery (64 FR 14308 and 64 FR 14517). It is unclear whether such potentially adverse effects to the offspring of hatchery supplemented fish spawning naturally above the dams also constitute adverse effects to the ESU.

6.1.1.4 Effects of Seasonal Water Management and Flow Fluctuations on Incubation Habitat

Reduced seasonal variability in flows below Willamette Project dams has likely reduced the potential for spring chinook salmon redd stranding, since average flows generally increase from August through December, and decrease gradually in January and February to levels that are still higher on average than occur during the spawning period. Any winter steelhead redds that would be constructed in mainstem reaches of the South Santiam River could be more susceptible to stranding because of a more rapid flow reduction during the spring months, but the effect is likely to be minor to negligible if the redds are constructed nearer the channel thalweg. Most steelhead spawning occurs in tributaries unaffected by Willamette Project flow releases.

6.1.1.5 Effects of Daily Flow Fluctuations (Ramping Rates)

Load-following facilities are likely to adversely affect salmonid fry and juveniles in reaches immediately downstream of dams. Generally, any USACE facility resulting in a drop in river stage greater than two inches per hour can be expected to cause stranding of listed fry (when they are present), and of other fish using margin habitat where bed slopes are gradual and cobble substrates predominate (Hunter 1992). Ramping rate restrictions and resultant water level fluctuations vary with project; project-specific effects are identified in the respective subbasin sections below.

6.1.1.6 Effects of Flood Control Operations

Operation of the thirteen Willamette Project dams and reservoirs for flood control may adversely affect listed salmonids directly because of changes in flow rates and water quality. As described in Section 2.1.2.1, a typical flood control operation involves a rapid reduction in project releases during the early, rising flood stages upstream of the reservoir to reduce flood impacts downstream as much as possible. The flows are then held low for a variable period of time that depends on antecedent and flood characteristics, and subsequently re-released as the flood recedes. With respect to what fish experience, flow rates below Willamette Project dams decrease suddenly, stay low for anywhere from a day or two, to several weeks or more depending on flood and location in the basin, and then increase to a level that is higher than before the flood and stay that way for a protracted period of time compared to the natural hydrograph (until the flood water volume has been passed through the reservoir). Figure 6-1 shows this operation for the dams located on the Middle Fork Willamette River in response to two successive events during the 1996-97 flood season.

These features of flood control operations may result in stranding of fish during the initial downramp, prolonged dewatering of salmonid spawning areas containing redds until flows rise again, flushing of fish from refuge or rearing habitat as the flows drop and redistributing them again as the flows rise, and influence distributions and fish behavior during the protracted flood flow release period. The downramping phase may also expose reservoir sediments to erosive forces leading to increased turbidity downstream from the reservoir water, and possibly to bank collapse downstream that would be associated with inputs of fine sediments to the stream. These effects are addressed individually below.

Downramping rates vary with antecedent conditions, flood event, dam, and physical stream channel characteristics. Maximum daily downramping rates calculated for each project during

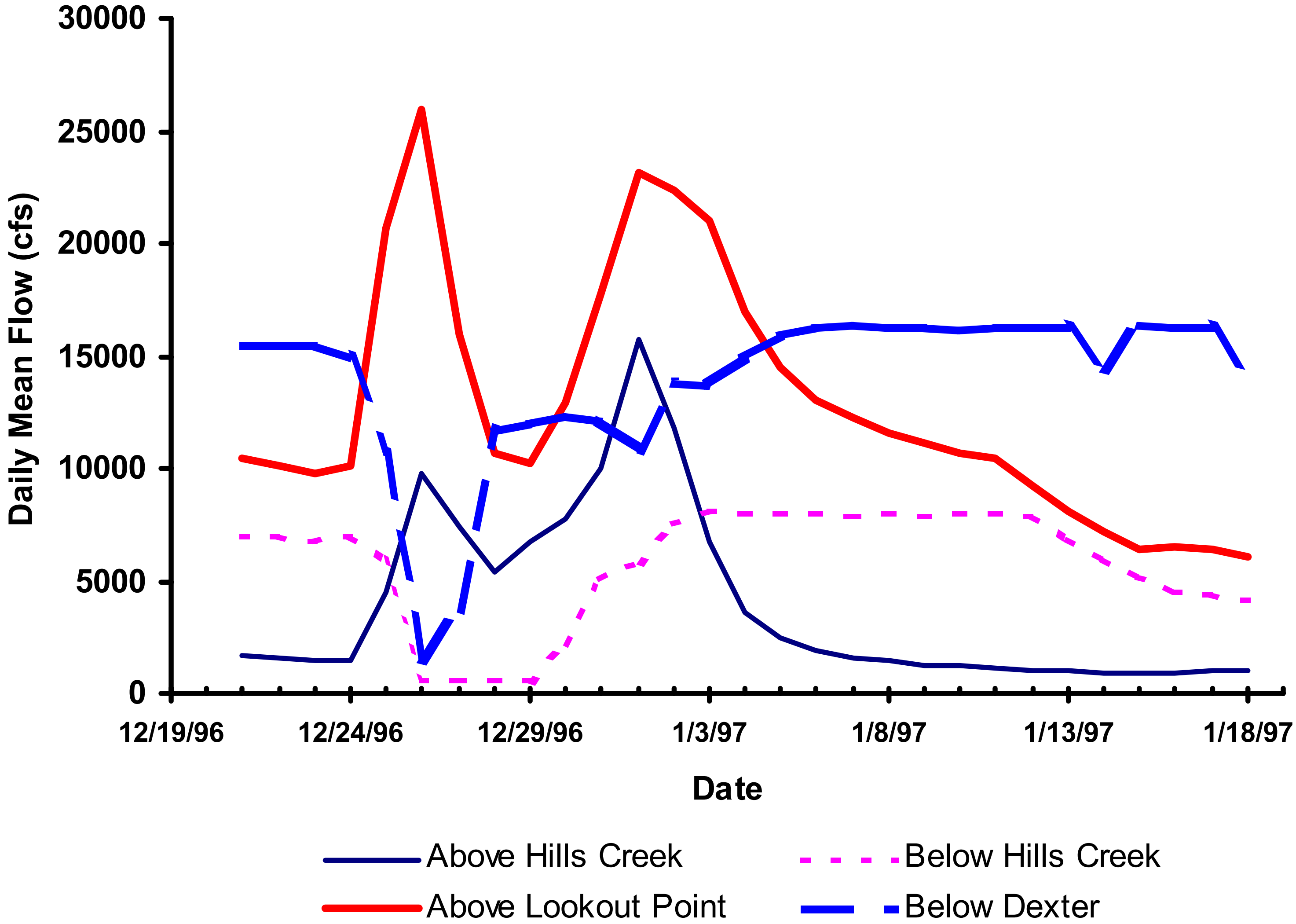


Figure 6-1. Example of a flood control operation in the Middle Fork Willamette River.

the 1996-97 flood season ranged from -70 cfs per hour at the gage below Cottage Grove Dam (12/8/96) to -560 cfs per hour below Hills Creek Dam (11/20/96). These are generally within project-specific ramping rate criteria, as described in Chapter 2 and Section 6.1.1.5, and thus may have relatively little adverse effect on listed fish species, with the possible exceptions noted in Section 6.1.1.5. However, no studies have been conducted to identify expressly what the critical ramping rates are below Willamette Project dams, so this interpretation is speculative. There is limited anecdotal evidence of stranding occurring during flood control operations. Thompson et al. (1966) noted that flood control operations resulted in stranding of fish in side channels and pools, resulting in heavy mortality. Hutchison et al. (1966b) noted this to be a problem particularly below Dexter Dam. It is generally unknown presently whether flood control operations adversely affect listed fish species through stranding (J. Ziller, ODFW Springfield and R. Lindsay, ODFW Corvallis, personal communication January 2000).

Dam operations during the fall typically are directed at restricting spring chinook salmon spawning activity to portions of the channel bed that do not become dewatered during flood control operations, as described in Chapter 2. There is no such guarantee for winter steelhead that may spawn below dams during the winter because of high flows during flood events. However, it is unlikely that steelhead spawn during a flood, so the point may be moot for that case. Even if redds were to become dewatered, there is evidence that salmon and steelhead embryos may be able to withstand temporary dewatering for up to several weeks (Reiser and White 1983; 1990). Hence, it is unlikely that flood control operations result in significant adverse stranding effects to listed salmon and steelhead embryos incubating in the streambed below Willamette Project dams.

Li et al. (1984) noted that flood releases from Lookout Point Reservoir during early June appeared to have flushed fish downstream from their study reaches, and a similar effect may occur during flood control operations. Giannico and Healey (1998) determined that flow increases resulted in emigration of coho salmon in smaller streams. Listed fish could likewise be displaced from their usual habitat and resting locations in response to flood control operations at Willamette Project facilities, but it is unclear whether the effect is adverse. No studies or anecdotes were identified during the preparation of this BA that pertained specifically to the effects of displacement or flushing in the Willamette River system, other than that they probably occurred. There are a number of factors that influence whether fish are vulnerable to the effects of displacement by fluctuating flows, including species, lifestage and stage of development, and water temperature (e.g., Ottaway and Clarke 1981). Juvenile salmonids may become more susceptible to predation as they become displaced, but there is typically a concomitant increase in turbidity that makes predators less effective (Gregory and Levings 1998). Displacement probably also occurred naturally during floods prior to dam construction, including through streambed disturbance by winter floods which would have influenced juvenile salmonids and other fish that resided within the surface substrate. It is unknown whether effects of displacement due to current flood control operations are more or less adverse compared to pre-dam conditions.

As described in Section 6.1.2.3.3, construction of the Willamette Project dams and reservoirs has resulted in changes downstream to the character and quantity of fine sediment. The average size of fine sediment is smaller, and bank erosion appears to be a replacement source for coarser sediments (Wentz et al. 1998). Flood control operations have the potential to result in increases in fine sediment levels downstream of the dams because of the collapse of saturated streambanks downstream of the dams when the water level drops too quickly, and erosion of the reservoir bed as the flood waters are subsequently released. It is unknown to what extent such effects exist, and whether they are adverse compared to pre-dam conditions. Bates et al. (1998) considered bank erosion during flood flows to be a source of fine sediments to the North Santiam River, but did not identify bank collapse, suggesting that this is not significant source in that system. Post-flood releases of denser, turbid water from the bottom of Detroit, Green Peter, and Lookout Point reservoirs, coupled with extended bank erosion caused by high flows, result in elevated turbidity levels lasting longer than historically (Larson 1980; Bates et al. 1998), and it is likely based on operational similarities that comparable effects may occur downstream of other Willamette Project dams. Turbidity levels measured at the City of Salem's water supply intake were measured as high as 140 NTU, compared with subsequent values around 10 NTU and less within two weeks after the February 1996 flood event (Bates et al. 1998). It is unknown whether and to what extent this measurement reflected adverse conditions because turbidity measurements are not a function of the absolute amount of suspended material present (WMO 1988; correlations can be performed with attendant error) and it is difficult to establish a threshold level for determining effects to fish (Newcombe and McDonald 1991). Water quality standards instead call for limiting rate increases in turbidity with respect to upstream control points as a surrogate (see Section 6.1.2).

In summary, flood control operations have the potential to adversely affect listed species, but it is presently unknown whether such effects are significant. More work is needed.

6.1.1.7 Specific Hydrographic Effects in Mainstem Willamette River

Streamflow augmentation by the Willamette Project has resulted in improved habitat quality in the mainstem river. Effects are addressed in Section 6.1.3.

Streamflow augmentation in August and September has contributed to the survival and ability of fall chinook, summer steelhead, and coho salmon to migrate upstream above Willamette Falls to spawning areas (USACE 1982). These species interact and compete with native spring chinook salmon and winter steelhead stocks. To the extent that interbreeding, habitat competition, and increased fishing pressure have adverse effects on native stocks (Kostow 1995), improved passage and habitat conditions for non-native stocks caused by increases in summer streamflow from Willamette Project facilities has likely had an adverse effect on native stocks. The degree of effect has not been quantified, however.

6.1.1.8 Specific Hydrographic Effects in Santiam River Subbasin

Big Cliff Dam releases are required presently to result in stage changes that are less than 3.6 inches per hour. This rate is greater than 2 inches per hour and thus could potentially cause stranding of Upper Willamette chinook salmon and steelhead fry during the months of February through September, according to emergence periodicities (ODFW 1990c) and anticipated growth rates. The extent of potential stranding is unknown, but may be small because much of the channel below Big Cliff Dam is confined, with relatively few cobble bars present on which fry could strand. Most fry are expected to occur in the vicinity and downstream of the Little North Santiam River, the most upstream significant recruitment source, where decreases in stage are attenuated to less than 2 inches per hour. Permitted flow fluctuations are expected to attenuate rapidly in the downstream direction within several miles; the attenuation may be facilitated additionally by the Minto Weir that is located approximately two miles downstream, which causes a minor backwater effect. Hence, flow fluctuations below Big Cliff Dam are not expected to result in significant fry stranding downstream.

Daily water level fluctuations adversely affect potential spawning habitat of anadromous and resident fish in the Middle Santiam River below Green Peter Dam. Ramping rates are unrestricted and highly variable, where water levels may change by five to fifteen feet daily (USFWS 1961; USACE 1989a). Load following operations would also be expected to strand juvenile salmonids of all species, and adult resident trout. No salmon or steelhead are passed through the Green Peter project presently, but adverse effects could occur if runs were to be restored. Effectively, the length of the Middle Santiam River between Green Peter Dam and Foster Reservoir may be unsuitable for fish because of the magnitude of flow fluctuations.

A 1996 field study of instream flows below Foster Dam and Big Cliff Dam determined that upstream passage was generally not a problem in the lower South and North Santiam rivers. One riffle was noted to be potentially a problem at the surveyed discharge (1,160 cfs release from Big Cliff Dam) because of shallow water (Jones et al. *no date*). However, it was concluded that the riffle was not preventing passage of chinook salmon; if it did, pools in the North Santiam River provide good holding habitat until the fish are ready to continue migration upstream.

6.1.1.9 Specific Hydrographic Effects in McKenzie River Subbasin

Analysis of effects in the McKenzie River is confounded by the simultaneous construction of the Carmen/Trail Bridge dam system, and it is difficult to allocate effects specific to the two USACE projects. Blue River controls runoff from approximately 9 percent of the area above the USGS gage on the mainstem McKenzie River near Vida, Cougar Dam controls runoff from approximately 22 percent, and Carmen/Trail Bridge dams control runoff from approximately 20 percent. Using this as a rough guide, the Blue River and Cougar facilities may have been responsible for approximately 60 percent of observed hydrograph changes in the mainstem downstream (ignoring possible climatic variation) although this number is probably too low considering that they hold proportionally more flood water than the Carmen/Trail Bridge complex.

Figure 6-2 depicts the contributions of the South Fork McKenzie and Blue rivers to the mainstem McKenzie River, before and after the projects were constructed. Before Cougar Dam, the South Fork McKenzie River contributed proportionally more flow to the mainstem McKenzie River in winter months, whereas now the South Fork contributes proportionally more flow during late summer and fall months. The average summer/fall contribution of the South Fork has resulted in an increase in the corresponding flows of the mainstem by about 22 percent. Blue River shows similar but weaker patterns (Figure 6-2). The average increase in summer/fall flows of the McKenzie River due to contributions from Blue River is about 15 percent. The total increase from both projects for the McKenzie River during summer/fall is more than 35 percent (USACE 1995a).

The effects of constructing Blue River and Cougar dams on instream fish habitat availability have not been evaluated, but may not be significantly adverse. Average monthly flows in the mainstem McKenzie River are relatively steady below Blue River and exhibited less dramatic change after dam construction than reaches below Willamette Project facilities in the other subbasins (Appendix F). Effects on mainstem McKenzie flows have generally included a reduction in the 10-day mean flow from February through June, and a measurable increase in flow during August through October. Ten-day mean flows of the pre-project period (1925-1962)

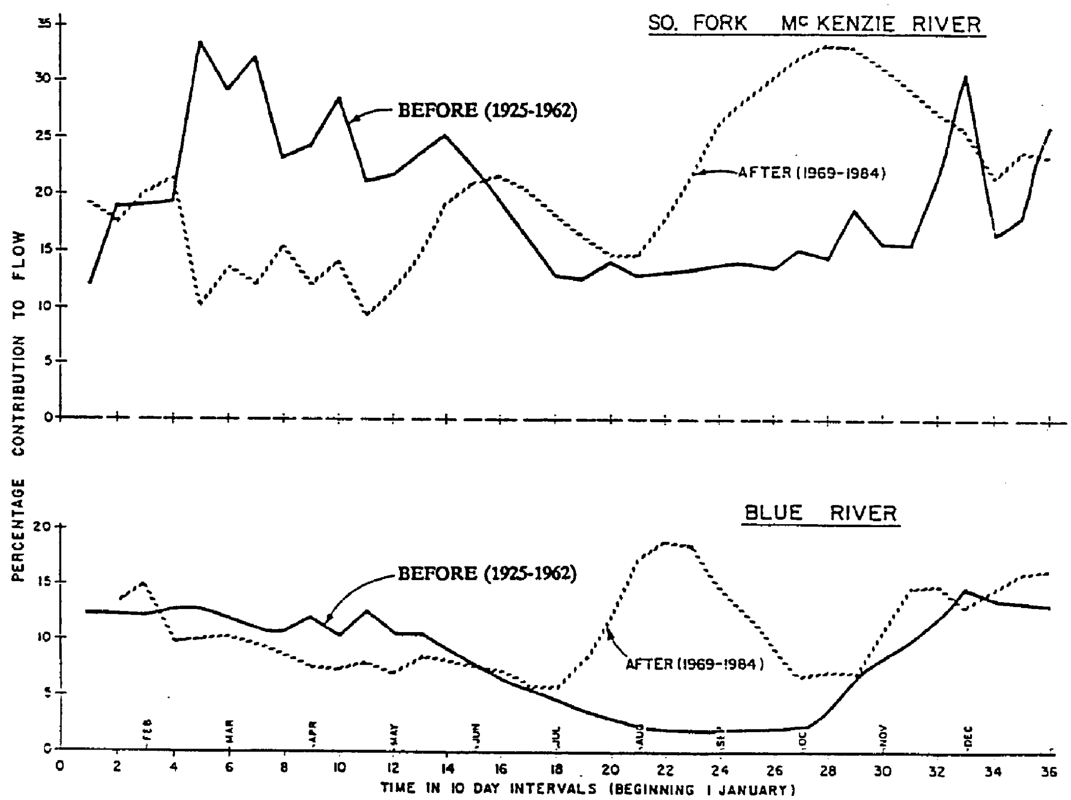


Figure 6-2. Contribution of Blue River and South Fork McKenzie River to flow in the mainstem McKenzie River before and after construction (USACE 1995a).

ranged from a high of about 5500 cfs during winter, to a low of 1750 to 2300 cfs during summer. Flows of the post-project period (1969-1984) ranged from a high of 7500 to 8000 cfs in December and January to a low of 2600 to 3000 cfs during summer. This change represents flow increases of 30 to 50 percent during summer and corresponding decreases in late winter and spring (USACE 1995a).

Blue River and Cougar dam releases intended for summer flow augmentation generally exceed flows from all other Willamette Projects during July and August. Blue River is drawn down first, then Cougar Reservoir. At the beginning of the flow augmentation season, discharge is increased at Blue River Dam until a maximum of 500 cfs is released. Discharge from Cougar Dam is increased subsequently to 800 cfs. As a result, the effects of Blue River on flows and water temperatures in the mainstem McKenzie River are greater during the summer months, particularly in mid-August, whereas effects of Cougar Dam are greater during the fall, around October. The result of this difference in drawdown schedules is a high, stable flow in the summer for the mainstem McKenzie between the confluence of the Blue River and Leaburg Dam. The seasonal pattern of high deviations in winter (4000 to 5000 cfs) and low in late summer (500 to 600 cfs) for the McKenzie follows the same pattern as for Blue River and the South Fork (USACE 1995a).

Daily flow fluctuations are not expected to strand fish in the South Fork McKenzie River under normal base load operations at Cougar Dam. Stranding of juvenile salmon, bull trout, and introduced steelhead could potentially occur on bars under less common load following operations, but it cannot be determined whether the normal ramping rates (500 cfs per hour during high flow and 200 cfs per hour during low flow) would result in stranding because the corresponding changes in stage have not been evaluated in this context.

6.1.1.10 Specific Hydrographic Effects in Middle Fork Willamette River Subbasin

Operations at Fall Creek Dam have increased summer and fall flows in lower Fall Creek over historic conditions. However, current flow releases typically do not meet recommended flows for spawning and incubation in Fall Creek below the dam (Tables 6-3, 6-4, and 6-7; USACE 1982). Most spawning in Fall Creek occurs presently upstream of the reservoir. Little if any spawning activity was noted below the Fall Creek dam site in the 1930s despite the abundance of spawning habitat (McIntosh et al. 1995). It is possible that Fall Creek never supported significant spawning in that reach because of naturally low flows (Appendix F). Limited natural spawning may have occurred locally in Little Fall Creek instead, during high flow years (ODFW 1990f; Connolly et al. 1992a).

Rapid flow fluctuations are likely to adversely affect listed fish below Fall Creek Dam. Stranding of adults was noted to be significant below Fall Creek when releases were dropped within a day from 150 cfs down to 50 cfs (USACE 1982). Present operation of Fall Creek (Section 2.6.2) includes an alternating summer flow release schedule between 150 cfs and lower flows, with a potential for adverse hydrographic effects to occur accordingly. USACE (1982) also noted that large fluctuations made it impractical to recommend spawning flows below the dam. Downey and Smith (1992) noted that reducing flows by half from 1500 cfs for a week in early September to meet the minimum pool scheduling goal may adversely affect bank stability, fish populations, aquatic invertebrate production, and angling opportunities below the dam.

Fall Creek flows are also less than half the recommended rearing flow rate nearly half the time (Tables 6-5 and 6-7; USACE 1982; Moffatt et al. 1990). However, since flow releases during the summer, when rearing habitat limitations are most critical in lower Fall Creek, are greater than historic, operation of Fall Creek Dam is unlikely to adversely affect juvenile salmonid habitat through hydrographic effects other than rapid flow fluctuations.

Maintenance of an Oregon chub population below Fall Creek dam during the summer appears to be successful (Scheerer et al. 1998), suggesting that operations there are not adversely affecting the species' summer habitat quality.

Parkhurst et al. (1950) noted that the lower portion of the Middle Fork Willamette River subbasin was subjected to "severe" floods. The lower 35 miles of the river were noted to have excellent appearing spawning habitat that was rarely used. Whether this was because of the effects of flooding is unknown. That habitat is now used because Dexter Dam blocks upstream passage, but flood control afforded by the four dams in the subbasin effectively provides protection against the effects of severe floods on incubation success in the mainstem.

A 1996 field study of instream flows below Dexter Dam determined that upstream passage was generally not a problem in the lower Middle Fork Willamette River (Jones et al. *no date*). Fish passage is not provided at Dexter Dam, but hatchery fish have been trapped and hauled to above Fall Creek Reservoir.

Ramping operations at Hills Creek Dam have the potential to adversely affect listed salmonids in the Middle Fork Willamette River. No chinook salmon use the affected reach presently, but this species could be affected if plans for reintroduction are finalized (USACE 1997). Recently introduced bull trout that may reside in Hills Creek Reservoir could migrate downstream through the dam, but probably would not be adversely affected by ramping operations because juveniles and adults of the species generally reside in the deeper parts of the channel (Goetz 1989) that are always inundated.

6.1.1.11 Specific Hydrographic Effects in Coast Fork Willamette River Subbasin

Two factors suggest that present operations do not result in adverse hydrographic effects on listed fish species: (i) summer and fall flows are increased over pre-dam flow rates; and (ii) chinook salmon are generally not present except for occasional hatchery strays.

Increased summer flows in the lower Coast Fork Willamette River would be expected to benefit rearing juveniles originating from production in the Middle Fork Willamette River subbasin, although this may be influenced by water temperature effects (Section 6.1.3).

6.1.1.12 Specific Hydrographic Effects in Long Tom River Subbasin

Summer flow releases from Fern Ridge Dam are increased over pre-dam flows (Appendix F), representing an improvement over historical baseline conditions. There are no known adverse effects related to hydrograph changes in the Long Tom River. No listed species reside currently in the subbasin.

6.1.2 Water Quality Effects

The effects of the Willamette Project on water quality and the resulting effects on listed fish species depend on numerous variables, including: water quality parameter, level or concentration reached by a parameter in the rivers downstream of USACE dams, level or concentration needed to produce an effect, whether the effect is chronic or acute, location in the system relative to refuge habitat, location in the system relative to water quality influences that do not originate from Willamette Project facilities or operations, instream hydrodynamic transport processes and chemical reactions involved, background and mitigating attributes of receiving waters, and fish species and life stage (e.g., egg, alevin, juvenile, smolt, adult) present.

The parameters that are potentially influenced by the Willamette Project include water temperature, dissolved oxygen, pollutant concentrations, and nutrient levels. These parameters and their effects are described below.

6.1.2.1 Potential Water Quality Effects

Changes in water temperature are the greatest potential water quality-related influence of the Willamette Project on the Willamette River basin's aquatic ecosystem. Water temperature criteria vary by species and lifestage and depend on acclimation temperature and other stresses caused by poor water quality. Extreme water temperatures (i.e., too warm or too cold) influence listed fish and their food in terms of: physiological processes including growth rates, metabolism, energy available for feeding, and stress; susceptibility to disease; and reproductive, migratory, over-wintering, and general behavior. Table 6-9 lists biological temperature criteria compiled from a number of sources for present and candidate ESA-listed fish species of the Willamette River basin. The limits in the table are likely accurate to within roughly ∀1.0EC, depending on interpretation of available information. Bull trout temperature criteria are presently the most uncertain and may be subject to change in the future as better information and data become available. The data in Table 6-9 are assumed to be of the correct order of magnitude for evaluating temperature effects in the Willamette system.

Table 6-9. Water temperature criteria for listed and candidate fish species potentially influenced by water temperature effects of the Willamette Project (Compiled from: Bell 1991; ODEQ 1995; McCullough 1995; Buchanan and Gregory 1997; Scheerer 1999). Key to abbreviations in table: F=Fall run, Sp=Spring run, Su=Summer run; M=Migration; Di=Disease; R=Rearing; H=Holding.

		Temperature Criteria (C)			
Species	**Lifestage**	**Optimum/ Preferred**	**Avoidance/ Tolerance**	**Stress/ Delay**	**Upper Lethal Limit**
Chinook Salmon	Adult	H: 8-12.5	All: 9.4, 14.1 F: 10.6, 19.4 Sp: 3.3, 13.3 Su: 13.9, 20.0	M: 21.0; Di: 15.5	25.0
	Spawning		5.6, 12.8	16.0	
	Incubation	4.5-12.8	1.7, 14.4		
	Juvenile	R: 7.2-15.6		R: 19.1 M: 18.3	R: 22.0 M: 18.3
Steelhead Trout	Adult	10.0-12.8	7.2, 14.4		23.9
	Spawning		3.9, 9.4		
	Incubation	10.0			
	Juvenile				
Coho Salmon	Adult	11.7-14.4	7.2, 15.6	21.1	25.0
	Spawning	4.4-9.4			
	Incubation	4.4-13.3			
	Juvenile	M: 7.2-16.7 R: 11.8-14.6	3.3, 20.3	20.3	25.0
Chum Salmon	Adult	11.1-14.4	8.3, 21.1	21.1	25.6
	Spawning	7.2-12.8			
	Incubation	4.4-13.3	4.4, 14.4		
	Juvenile	M: 10.0	M: 6.7, 13.3		25.6
Bull Trout	Adult	M: 10-12 9.0-13.0	4.0, 18.0	20.0	
	Spawning	5.0-8.0	4.0, 10.0		
	Incubation	1.0-6.0			
	Juvenile	4.0-10.0			

Table 6-9. Water temperature criteria for listed and candidate fish species potentially influenced by water temperature effects of the Willamette Project (Compiled from: Bell 1991; ODEQ 1995; McCullough 1995; Buchanan and Gregory 1997; Scheerer 1999). Key to abbreviations in table: F=Fall run, Sp=Spring run, Su=Summer run; M=Migration; Di=Disease; R=Rearing; H=Holding.

		Temperature Criteria (C)			
Species	**Lifestage**	**Optimum/ Preferred**	**Avoidance/ Tolerance**	**Stress/ Delay**	**Upper Lethal Limit**
Cutthroat Trout	Adult	9.4-12.8			22.8
	Spawning	10.0	6.1-17.2		
	Incubation	4.4-12.8			
	Juvenile				
Oregon Chub	Adult				
	Spawning	>16			31
	Juvenile				

Water temperatures below a dam are influenced strongly by the temperature of the water in the impoundment and can be the most important influence of dams on water quality for fish. Water temperatures in the impoundment depend on the volume of water stored, which is a function of the dimensions of the impoundment. Large dams with deep reservoirs facilitate development of a thermocline in the impounded water. Water drawn from near the bottom of the reservoir and released downstream will then tend to be cooler than the water entering the reservoir during the summer (i.e., historic conditions), and warmer in the winter. Water in the surface layers will tend to be warmer than water flowing into the reservoir during the summer because of the relation between increased surface area and solar thermal input. Water drawn from the upper layer may thus be warmer downstream than before the dam was constructed. Depending on the reservoir, water temperatures may be warmer in the fall for a longer duration than historically, potentially resulting in delayed upstream migration of adult fall-spawning salmon, and premature emergence of their progeny in downstream reaches.

Depending on duration and magnitude, temperature changes can result in significant changes in fish species and aquatic community structure. A warm-water community may arise where a cooler-water community existed before, or vice-versa, depending on the size and depth of the reservoir and where the water is drawn from. Alternatively, the magnitude of change may be insufficient to cause community shifts, but may result in stress, changes in life history stage periodicity, and facilitate disease if the new temperatures are outside of the optimal range for a species.

The length of river over which temperature changes occur downstream of a dam depends on factors that influence the rate at which the river can re-equilibrate its temperature to the daily atmospheric temperature cycle, and inflow (surface and ground) water temperatures. These factors include air temperature, mainstem and accretion/tributary flow rates and water temperatures, wind speed, total radioactive energy input (which varies with latitude and cloud cover), topographic aspect and shading, and vegetative shading. The relative importance of each varies seasonally. These factors also influence water temperatures within the impoundment.

Changes in water temperature may also influence dissolved oxygen concentrations. In general, as temperature increases, respiration rates of aquatic biota increase and oxygen solubility decreases (warmer water contains less oxygen than colder water). Oxygen concentrations that are reduced significantly below saturation can lead to reduced embryo survival, retarded embryonic development, reduced growth rates of fish, increased susceptibility to toxic substances, reduced food consumption, altered metabolic rates, and generally stress fish. Fish may avoid areas where dissolved oxygen levels are below certain concentrations, which could result in delayed upstream migration. Low levels can be lethal. Reduced dissolved oxygen levels may also influence aquatic invertebrate production. Under conditions of low oxygen levels, upstream migrating salmonids may experience reduced swimming speed and leaping capacity, affecting their ability to negotiate passage barriers and fishways (ODEQ 1995).

High head dams cause elevated levels of total dissolved gas (TDG) over a certain reach length below the structure when water is spilled. High saturation levels of TDG can cause physiological conditions harmful to fish. Symptoms include exophthalmia (eye protrusion), embolisms in the bloodstream and bubble formation in skin and tissues, and hemorrhaging. Depending on the species, lifestage, water temperature, water depth, and severity of exposure, fish may recover completely, become disabled, or die (Weitkamp and Katz 1977). Fish are more susceptible to gas bubble disease in shallow water because they cannot swim to deeper elevations where increased hydrostatic water pressure helps keep gases in solution. Levels above 110 percent of saturation are considered adverse when water is approximately one meter deep or less, and above 120 percent when water is approximately 2.5 meters or deeper. Mortality has been noted when levels approach 115 percent in shallow waters (Weitkamp and Katz 1977; Bell 1991; USACE 1998b; Mesa et al. 2000).

Changes in flow regime can result in changes in water quality by influencing the effects of dilution. Water quality exceedances have the potential to kill or stress fish depending on the parameter, its concentration, and time of year. Flow rate influences the concentration of a parameter. Toxic substances may affect listed fish either acutely as in the form of a fish kill, or chronically in the form of physiologic impairments. Chronic effects can be realized either directly from dissolved substances in the water column, or through food-chain contamination. Chronic effects are invariably more difficult to assess than acute effects. The concentration at which chronic effects are manifest is often difficult to establish for specific contaminants, and the degree of the effect will vary depending on local environmental conditions and biological adaptations such as acclimation and bioaccumulation. The effects of elevated metal concentrations to fish have been documented extensively (e.g., EPA 1986). High concentrations of metals can lead to acute toxicity and corresponding mortality of fish and other aquatic life. Concentrations that are lower but still above criteria threshold levels may impart a variety of chronic effects such as reduced growth, reproductive ability, and behavioral changes of fish (Chapman 1973; EPA 1986).

Changes in flow rate may also lead to changes in concentrations of constituents that then are more susceptible to chemical reactions. For example, critical habitat may be affected in cases where a chemical reaction changes the physical properties of the streambed (e.g., cementing) or where a contaminant binds temporarily within the stream environment and is released later, either gradually or suddenly, depending on water chemistry.

Aquatic invertebrates, an important food source of listed fish, may be affected by poor water quality either directly, or indirectly through habitat degradation, which can reduce production levels and result in changes in community composition. Reductions in invertebrate production could result in reducing carrying capacity for many fish species since the availability of food is reduced. Community changes may be important to juvenile salmonids if the shift is from a drift-based to a more substrate-based composition, and to Oregon chub if there is a shift from quiet water taxa to fast water taxa because of increased exchange with the main channel (USFWS 1998a). In reaches immediately downstream of dams, however, the released discharge may contain high concentrations of phytoplankton, zooplankton, and other aquatic invertebrates originating from the reservoir that are fed on by fish below the dam.

Because impoundments act as settling basins for suspended sediments originating upstream, the flows downstream of dams may be associated with reduced turbidity downstream when the reservoir is filled or filling. Reduced suspended sediment concentrations result in reduced physical stress to gills and improved oxygen exchange. Improved visibility can have both positive and negative effects: fish are better able to see their prey, but their predators are better able to see them. Reduced suspended sediments may lead to increased periphyton growth in streams because of greater light penetration, increased benthic invertebrate production, and improved feeding efficiency of filter feeders (Newcombe and MacDonald 1991). Alternatively, turbidity may be increased over pre-dam levels during drawdown periods when the reservoir bed becomes disturbed by faster moving water, and especially during a storm and flood control operations when significant erosion of the lake bed can occur. The increased turbidity downstream may adversely affect feeding efficiency and stress fish and invertebrates (Newcombe and MacDonald 1991).

Impoundments can experience significant algal growth that may end up as organic and nutrient matter discharged downstream, resulting in either increased productivity or water quality problems depending on amounts (Marcus et al. 1990). Increased algal growth may result in increased Biological Oxygen Demand (BOD) and diel shifts in dissolved oxygen concentration, and provide habitat for predators.

Table 6-10 lists water quality standards and criteria for the Willamette River basin established by the state of Oregon (summarized from Oregon Administrative Regulations). Basins that do not meet individual criteria are noted on the State's 303d list of water bodies impaired by water quality, as required by the Clean Water Act. Appendix G depicts water quality impaired streams that are included in the 1998 303d list because of adverse levels of water temperature, dissolved oxygen, and other water quality parameters.

6.1.2.2 Water Temperature Effects

Willamette Project facilities have resulted in adverse changes to downstream temperature regimes because of thermal energy storage, temperature stratification, and the depth from which water is drawn in the reservoirs. Project construction and operation have caused shifts from the natural regime that can have adverse effects on adult, incubation, and juvenile lifestages of selected listed species (USACE 1997). In general, water temperatures in the rivers downstream of each project are cooler in the spring and early summer, and warmer in the fall and early winter, than before the dams were constructed. This is because the water stored in the reservoirs takes longer to warm up in the spring than the impounded length of river did before the dam was constructed. Water drawn near the bottom of the reservoir is also colder in the spring because of thermal stratification. Over the summer, the reservoir water warms. In the fall, when river temperatures naturally drop, the reservoir water is still warm because of the large thermal mass

Table 6-10. Relevant State of Oregon water quality criteria for the Willamette River basin.

Parameter	Water Body Class	Criterion	Time Frame
Dissolved Oxygen (DO)	Salmonid spawning	Min = 11 mg/l or Min = 9 mg/l if Min IGDO [1] = 8 mg/l or 95% of saturation and Min IGDO = 6 mg/l	Incubation period
	Cold-water aquatic life	Min = 8 mg/l or 90% of saturation	Any time
		Discretionary: Min = 8 mg/l and	30-day mean
		Min = 6.5 mg/l and	7-day mean
		Min = 6 mg/l	Any time
	Cool-water aquatic life	Min = 6.5 mg/l	Any time
		Discretionary: Min = 6.5 mg/l and	30-day mean
		Min = 5 mg/l and	7-day mean
		Min = 4 mg/l	Any time
	Warm-water aquatic life	Min = 5.5 mg/l	Any time
		Discretionary: Min = 5.5 mg/l and	30-day mean
		Min = 4 mg/l	Any time
Water Temperature (WT)	Salmonid fish rearing = beneficial use	No measurable anthropogenic increase when WT> 17.8 C	Any time, except when air temp. during warmest 7-day period of year > 90th percentile of 7-day average daily maximum
	Willamette R. and sloughs, mouth to RM50	No measurable anthropogenic increase when WT > 20.0 C	Any time, except when air temp. during warmest 7-day period of year > 90th percentile of 7-day average daily maximum
Water	Native salmonid	No measurable	Any time, except when air

Table 6-10. Relevant State of Oregon water quality criteria for the Willamette River basin.

Parameter	Water Body Class	Criterion	Time Frame
Temperature (cont.)	spawning	anthropogenic increase when WT > 12.8 C	temp. during warmest 7-day period of year > 90th percentile of 7-day average daily maximum
	Necessary to maintain native bull trout	No measurable anthropogenic increase when WT > 10.0 C	Any time, except when air temp. during warmest 7-day period of year > 90th percentile of 7-day average daily maximum
	Ecologically significant cold-water refugia	No measurable anthropogenic increase	Any time
	Segments containing federally listed T&E species	No measurable anthropogenic increase that would impair biological integrity of listed population	Any Time
	Waters where [DO] is within 0.5 mg/l or 10% of saturation of WQ criteria	No measurable anthropogenic increase	Any Time
Turbidity	Natal stream	Anthropogenic: Max = 10% cumulative increase in NTU relative to upstream control point	Any time
pH	All	Min = 6.5, Max = 8.0, except impoundments existing 1/1/96 where all practicable measures have been undertaken to reach compliance	Any time
Total Dissolved Gas	Downstream of dams	Max = 110% of saturation relative to atmospheric pressure	Any time, except when flow > 10-year, 7-day average flood
	Hatchery receiving waters and waters < 2 feet deep	Max = 105% of saturation relative to atmospheric pressure	Any time
Toxic Substances	All	Per EPA criteria	Per EPA criteria

[1] IGDO = Inter-gravel Dissolved Oxygen Concentration

that is present. Discharges remain warmer than upstream inflows until the reservoir is drawn down, mixes, and equilibrates with ambient air temperatures (USACE 1995a; USACE 1997).

6.1.2.2.1 Specific Biological Effects of Temperature Regime Changes

Out of all of the listed species, spring chinook salmon are most vulnerable to temperature effects of the Willamette Project because of their reproductive timing and because they spawn predominantly in the mainstem rivers below the dams. Winter steelhead are affected less because they spawn and incubate during the spring when temperature effects are negligible, and spawning activity occurs predominantly in tributaries. Bull trout spawn upstream of the dams or in tributaries in the McKenzie River subbasin. Adult and juvenile chinook salmon, steelhead, and bull trout may be influenced by changes to water temperatures in the mainstem reaches during the spring, summer or early fall depending on the river and other factors.

Adult chinook salmon in the Willamette River basin use water temperature as a stimulus for upstream migration during the spring and summer months. Studies have identified a mean daily temperature of 11°C as the optimal temperature for prompting upstream migration in the Willamette River basin (USACE 1995a). Mean daily water temperatures below the optimal value generally cause the adult fish to hold in place. Due to thermal stratification and the depth of the outlet works in the reservoirs, the water temperature of releases made during the adult migration period are usually cooler than under pre-project conditions. Water withdrawal from the hypolimnion, which does not warm in the spring and summer like the temperature of the surface water, results in a reluctance by chinook salmon to move into and use reaches within several miles below dams. When adult migration is delayed long enough, the fish will eventually spawn in downstream areas that can be inferior in terms of incubation habitat quality compared with analogous habitat in upstream reaches.

The chinook salmon embryos incubate in the riverbed for several months before emergence occurs. The temperature of water released from USACE dams influences the length of the incubation process. The deeper, colder water of the hypolimnion is depleted first during flood control drawdown in early fall, followed by the warmer, upper layer of the epilimnion. The warmer-than-normal water that is released downstream in the fall and early winter accelerates incubation, leading to premature emergence of the young fish during winter instead of in the spring. Winter conditions are considerably less suitable and production of food organisms is less, thereby influencing survival of the young fish. Significant mortality is likely (USACE 1997).

Juvenile winter steelhead are susceptible to bacterial diseases when water temperatures exceed 16.5°C in the mainstem Willamette River (Buchanan 1976; ODFW 1998). High temperatures may also reduce ATPase activity and downstream migration rates. The dates at which temperatures reach 16.5°C in the lower Willamette River have ranged between April 30 and June 18, and averaged around late May. Delays in outmigration on the order of 1 to 3 weeks can have the potential to adversely affect juvenile winter steelhead as they migrate through the Willamette River (Buchanan et al. 1993).

6.1.2.2.2 Temperature Effects Specific to the Santiam River Subbasin

The USACE (1988) evaluated effects of the federal projects on river temperatures in the Santiam River subbasin by comparing measured water temperatures (i) above and below the projects in both the North and South Santiam River, and (ii) before and after dam construction in the South Santiam River subbasin only. Santiam River water temperatures are generally cool because the headwaters are located at high elevation, and tend to be 3-6°C cooler than temperatures in the Willamette River at their confluence. Summer water temperatures have been estimated to be up to 8°C cooler, and late fall and early winter temperatures up to 6 °C warmer, than before the dams were constructed (USACE 1995a).

North Santiam River

Detroit Reservoir is currently managed so that it is full during the summer for recreation purposes and drawn down in the fall in preparation for flood control. Water is withdrawn from near the bottom and there is a direct relationship between project operations and thermal effects of the projects on downstream waters, particularly in the summer and fall. Detroit Dam and Reservoir have had a measurable effect on mean daily water temperatures based on data collected above and below the dam (Figure 6-3) (USACE 1988). Temperature effects occur down to the confluence with the South Santiam (Hansen and Crumrine 1991).

From mid-June through August, discharge temperatures are approximately 3-5°C colder than inflow temperatures (USACE 1988). However, it has been estimated (sufficient water temperature data were not collected before the dams were constructed) that current Detroit Dam discharge water temperatures during this period may be as much as 8°C colder than historic, because water flowing between the inflow and outflow measurement locations (USGS gaging station number 14178000 [on the upper North Santiam River] and Big Cliff Dam, respectively) would have gained in temperature before the dams were built (USACE 1988). The cooler temperatures have adversely affected upstream migration of adult chinook salmon, and could

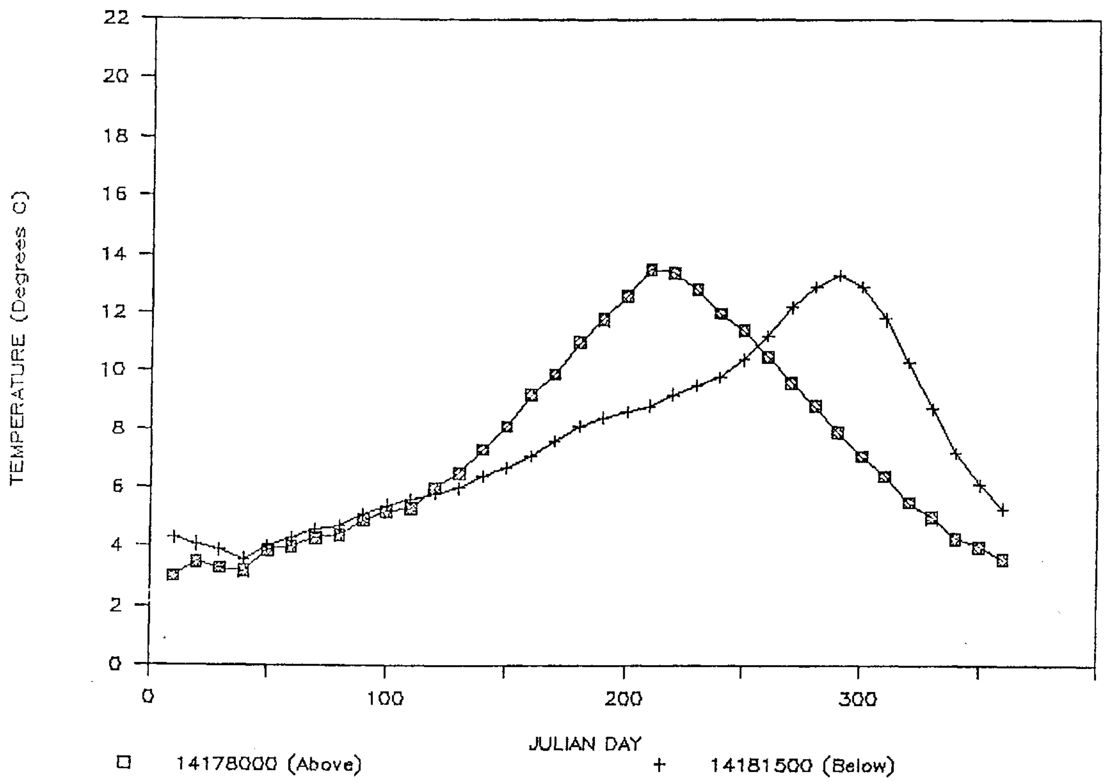


Figure 6-3. Comparison of mean daily water temperatures (10-day intervals) measured in the North Santiam River above Detroit Lake (USGS Station 14178000) and below Big Cliff Dam, Oregon (USGS Station 14181500); 1968-1985 (USACE 1988).

delay emergence of steelhead fry in redds constructed in the North Santiam River. Effects to steelhead fry have not been studied. Smolt emigration may also be delayed.

Water discharged from Detroit Dam in September through November is approximately 3-6°C warmer than inflow waters (USACE 1988). The warmer temperatures influence emergence timing of chinook salmon fry in the North Santiam River, and likely reduces their over-winter survival.

A study (USACE 1988) was conducted to estimate potential benefits from a change in the downstream water temperature regime by modifying the existing intake tower. Modification of the intake structure would allow selection of water temperature for release from the project by drawing water from different elevations in the reservoir. The project could be operated to restore stream temperatures in the North Santiam River to pre-project levels. Modeling studies conducted in the early phase of the Willamette Temperature Control Study suggest that natural flows may be duplicated (USACE 1988). The modeling studies assumed that a multilevel tower with six ports would be constructed at Detroit Dam. Enactment of the plan is subject to Congressional authorization and funding, which has yet to be appropriated.

Middle and South Santiam Rivers

Green Peter Reservoir is currently managed so that it is full during the summer for recreation purposes and drawn down in the fall in preparation for flood control. Water is withdrawn from near the bottom and there is a direct relationship between project operations and thermal effects of the projects on downstream waters, particularly in the summer and fall. Green Peter Dam and Reservoir have had a measurable effect on mean daily water temperatures based on data collected above and below the dam (USACE 1988).

Temperature effects of Green Peter Reservoir were not assessed directly by USACE (1988) because of insufficient data. Water temperatures above the lake were evaluated using data measured in Quartzville Creek, which has similar water temperatures to the Middle Santiam River where they enter Green Peter Reservoir. Comparisons with water temperatures measured in the South Santiam River below Foster Dam indicate that operation of Green Peter and Foster dams cumulatively reduces average water temperatures in the South Santiam River by as much as 7°C in the summer, and increases water temperatures in the fall and early winter by 1-3°C (Figure 6-4). A comparison of water temperature data measured in the Middle Santiam River near its mouth before dam construction, with temperature data measured in the South Santiam River below Foster Dam after its construction, indicates a similar trend (Figure 6-5). The similarity in magnitudes of temperature changes in Figure 6-4 and Figure 6-5 indicates that construction of Green Peter Dam has had the predominant effect on water temperatures in the South Santiam River below Foster Dam.

Water temperature effects in the South Santiam River decrease in magnitude with distance downstream below Foster Dam. Temperature differences near the confluence with the North Santiam River have been generally within ± 2°C of historic (Hansen and Crumrine 1991). Average water temperatures in the South Santiam River at RM 23, 14 miles downstream of Foster Dam, are reduced from pre-dam levels by about 5-6°C in the summer, and increased by about 1-3°C in the fall and early winter (Figure 6-6). Hence, the effect of Green Peter Dam is reduced by approximately 1-2°C over 14 miles as the river water temperature is warmed by radiation and air temperatures. However, the cooling effect is still significant during the summer, adversely affecting upstream migration of adult chinook salmon, and possibly delaying emergence of steelhead fry in any redds constructed in the South Santiam River below Foster

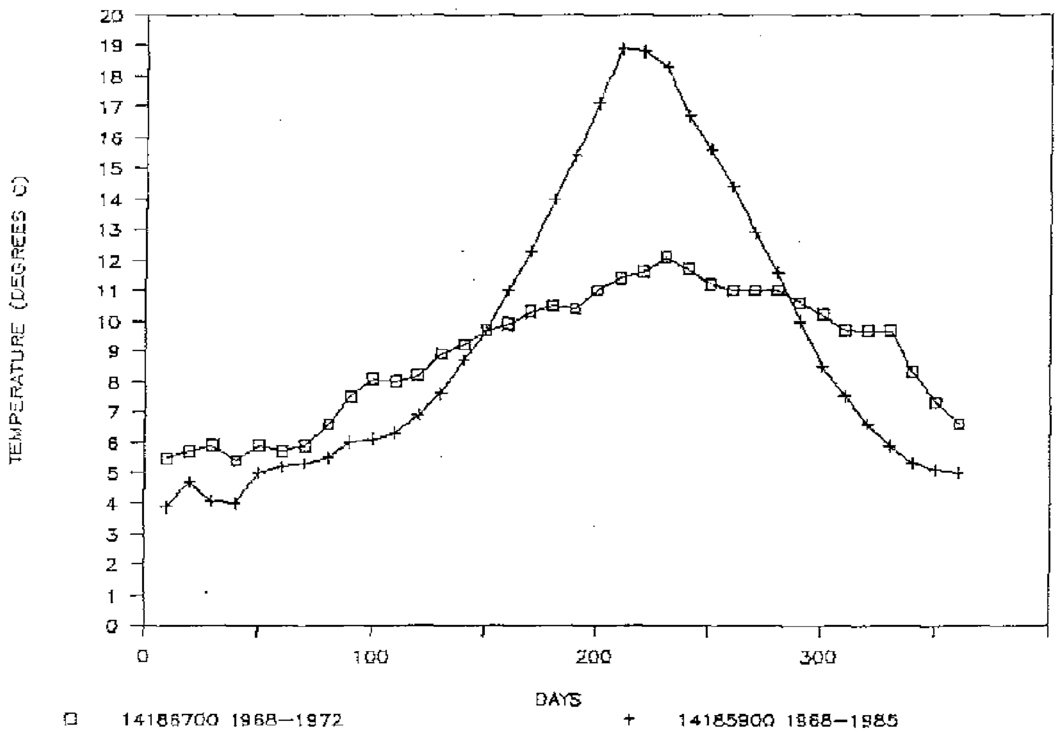


Figure 6-4. Comparison of mean daily water temperatures (10-day intervals) measured in Quartzville Creek (USGS Station 14185900; 1968-1985) above Green Peter Reservoir, and in the South Santiam River (USGS Station 14186700; 1968-1972) below Foster Dam, Oregon (USACE 1988).

Dam. Effects to steelhead fry have not been studied. Emigration of smolts may also be delayed. The warmer fall and early winter water temperatures also influences emergence timing of chinook salmon fry in the South Santiam River, and likely reduces their over-winter survival.

There is an authorized plan to change the downstream water temperature regime by modifying the existing intake tower at Green Peter Dam. Modification of the intake structure would allow selection of water temperature for release from the project by drawing water from different elevations in the reservoir. The project would be operated to restore stream temperatures in the Middle and South Santiam rivers to pre-project levels. Modeling studies suggest that the historic ("natural") temperature regime may not be duplicated completely, however, even with modification. The modeling studies assumed that a multilevel tower with six ports would be constructed at Green Peter Dam (USACE 1988). Enactment of the plan is subject to Congressional funding, which has yet to be appropriated.

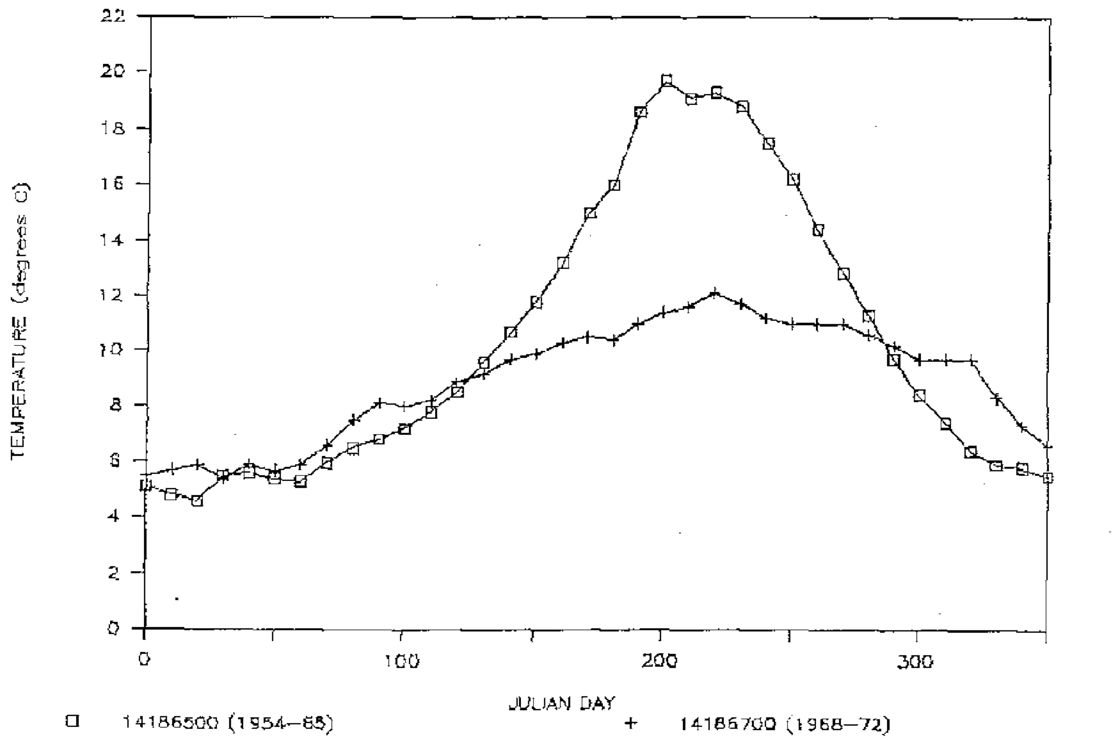


Figure 6-5. Comparison of mean daily water temperatures (10-day intervals) measured in the Middle Santiam River near its month (USGS Station 14186500 before construction of Foster Dam (1954-1965), and in the South Santiam River below Foster Dam, Oregon (USGS Station 14186700) after its construction (USACE 1988).

Santiam River

Water temperatures in the mainstem Santiam River do not appear to be influenced significantly by Willamette Project facilities. The influence of Detroit Dam has not been assessed because of insufficient pre-project temperature data. Water temperatures measured less than 2 miles downstream of the North and South Santiam confluence before and after construction of the Green Peter and Foster dams do not differ substantially (Figure 6-7) indicating that those facilities have relatively little influence on water temperatures below the confluence. This result also suggests that greater temperature equilibration occurs in the South Santiam River below RM 23 than above.

The general lack of a difference would suggest that project effects have been dissipated by the time water reaches Jefferson, Oregon. The dominant factor influencing river temperatures near Jefferson may be atmospheric conditions rather than Willamette Project effects.

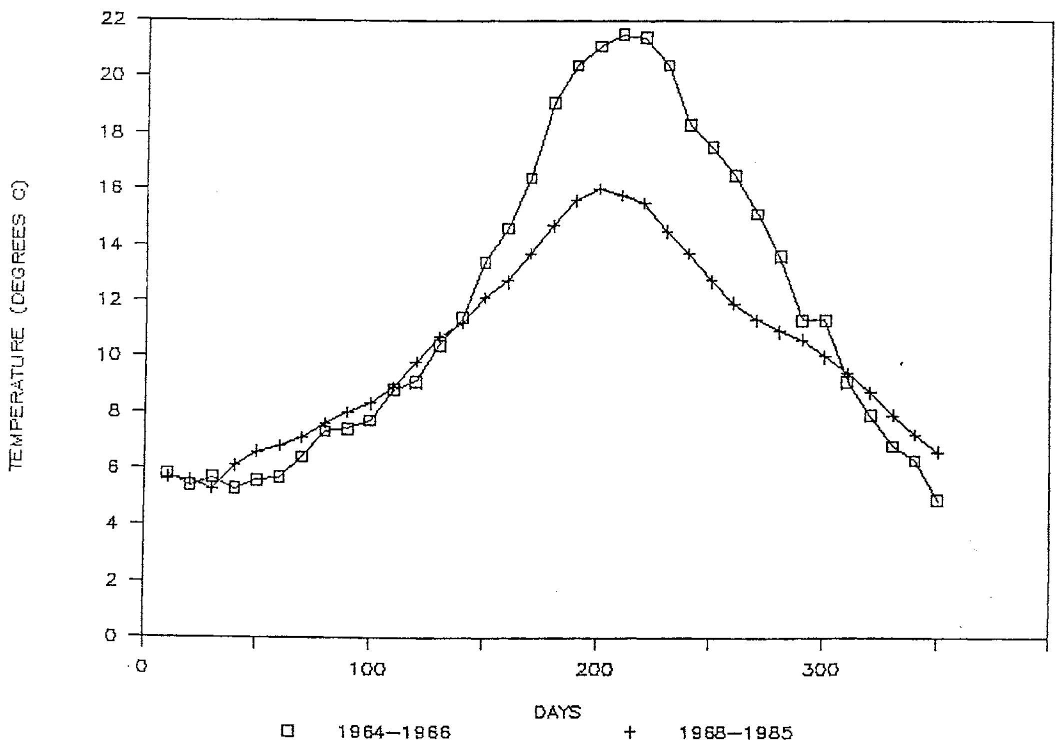


Figure 6-6. Comparison of mean daily water temperatures (10-day intervals) measured in the South Santiam River below Foster Dam, near Waterloo, Oregon (USGS Station 14187500): 1964-1966 (before Foster/Green Peter) and 1968-1985 (after Foster/Green Peter) (USACE 1988).

6.1.2.2.3 Temperature Effects Specific to the McKenzie River Subbasin

The Blue River and Cougar Reservoir projects have altered downstream water temperatures in their respective streams; temperatures are cooler in the late spring and summer, and warmer in the late fall and early winter than before the projects were constructed. Cooling occurs because water is drawn from outlets at the bottom of the deep, stratified reservoirs, where it is cooler than at the surface. Warming occurs as a result of fall drawdown operations when the warmer surface waters reach outlet elevations. Figure 6-8 depicts representative vertical profiles of water temperature measured in the two reservoirs in late spring (circa June). During that time, there were two temperature strata apparent in Blue River Reservoir and three in Cougar. At Blue River, the outlet is near the bottom of the reservoir (elevation 1,132 to 1,140) whereas the Cougar outlet is located about halfway up the abutment, at elevation 1,512 (the bottom of the reservoir is at elevation 1,275). In addition, Cougar Dam's outlet is in a bay that is connected to the main reservoir through a gap at elevation 1,500 feet. This feature limits the depth to which

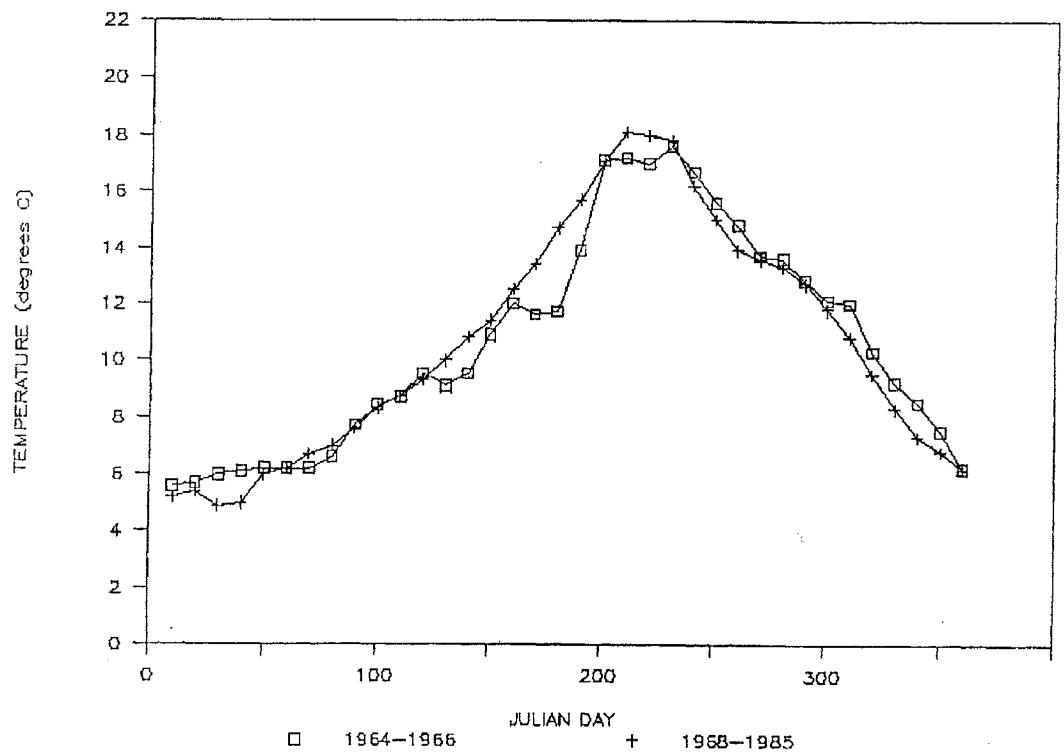


Figure 6-7. Comparison of mean daily water temperatures (10-day intervals) measured in the Santiam River near Jefferson, Oregon (USGS Station 14187500): 1964-1966 (before Foster/Green Peter) and 1968-1985 (after Foster/Green Peter) (USACE 1988).

reservoir withdrawals can affect the mixing and temperature of Cougar Reservoir. The mid-range temperature water extends to the level of the outlet, while the colder water extends to the bottom of the reservoir (Figure 6-8).

Figures 6-9 and 6-10 depict temperature conditions measured in Blue River and Cougar reservoirs, respectively, in 1984, and inflow and outflow water temperature variation over the same period. The figures show that the warm water in the lakes, which matches the water temperature flowing into the lakes, is floating high above the reservoir outlets. The deep, colder water is released initially. As the reservoirs are drawn down, the cooler water is depleted and warmer water of the metalimnion begins limited mixing, and the remaining water is generally warmer than the water flowing into the reservoirs at that time. Early seasonal storms cause the reservoirs to mix completely by late October or mid-November. Water temperature continues to

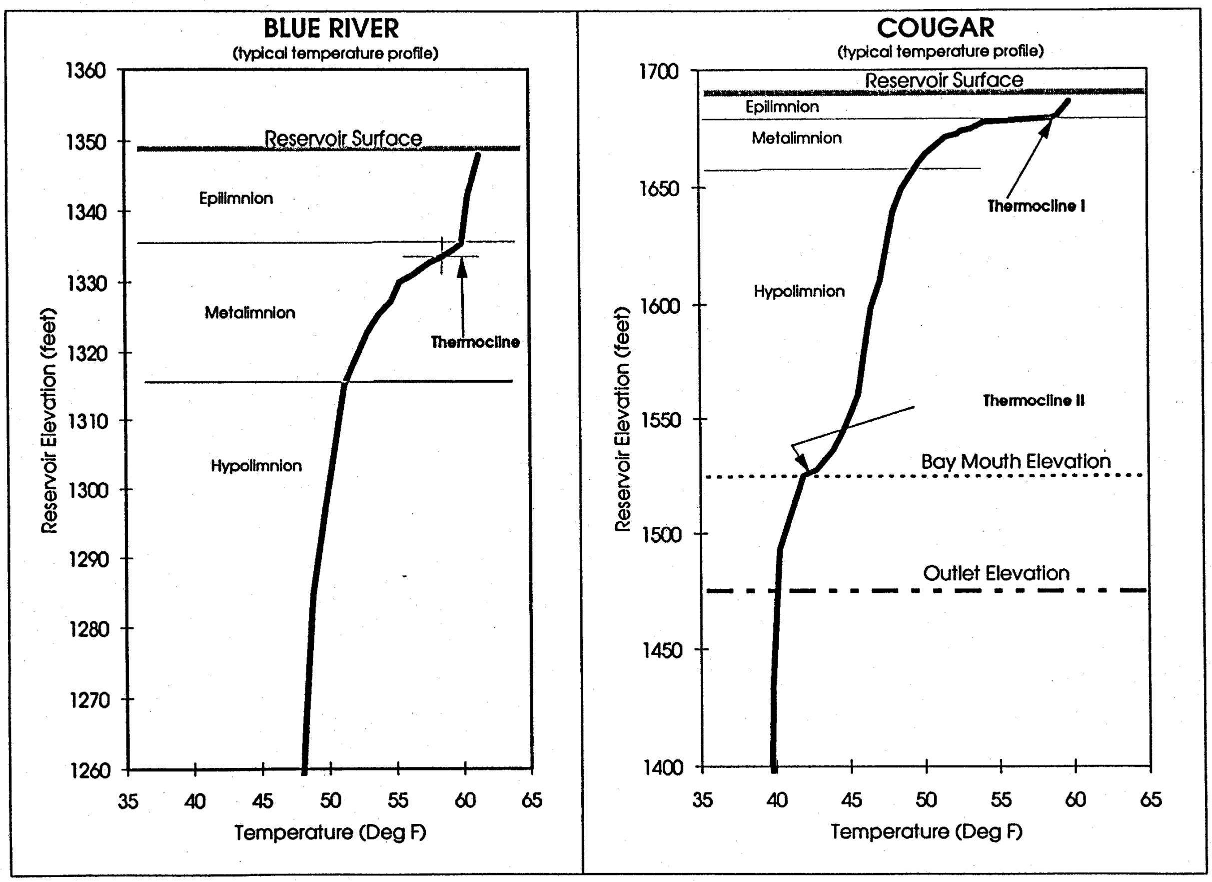


Figure 6-8. Representative water temperature profiles measured in June at Blue River and Cougar lakes (USACE 1995a).

fall through January, followed by a slow warming trend in early spring. Stratification of the reservoirs begins in about April.

The Cougar and Blue River projects have influenced temperatures in the mainstem McKenzie River to below Leaburg Dam, which is located on the mainstem McKenzie River at RM 38.8 and diverts a large amount of the McKenzie's flow through a canal to a powerhouse located near Walterville at RM 20.9. However, the magnitude of the effect is moderated considerably by mainstem flows originating above the South Fork McKenzie River and because some equilibration with ambient air temperatures occurs between Blue River and Leaburg Dam (ODFW 1990e). Average mainstem temperatures downstream of Leaburg Dam have been recorded to be as much as 1.2°C cooler than historic from June through early September, and 1.2°C warmer from mid-September through November (Morse et al. 1987, cited in ODFW 1990e). Studies have indicated that effects of USACE reservoir releases on water temperatures are relatively small downstream of Leaburg Dam, and are generally undetectable near Vida

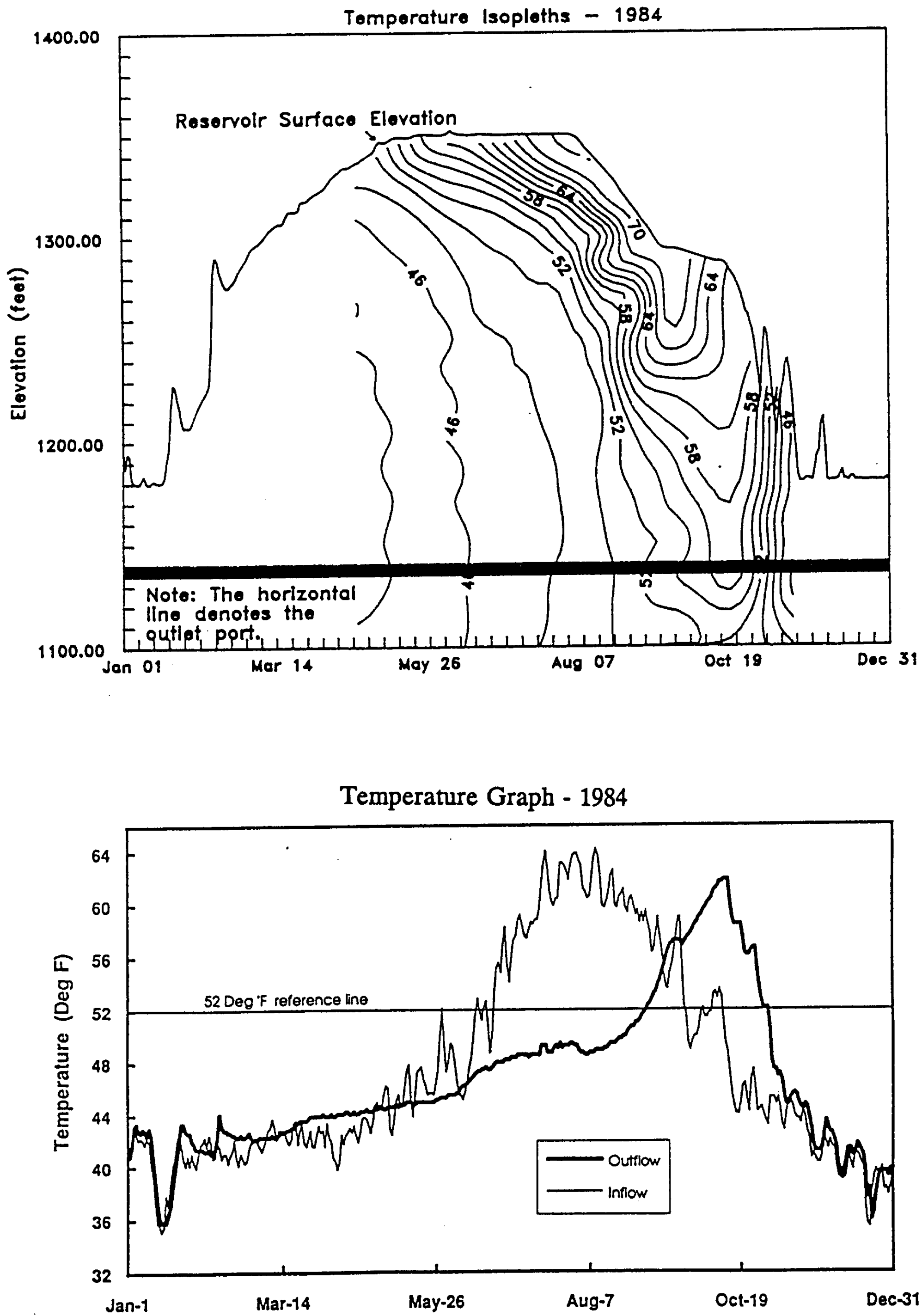


Figure 6-9. Thermal conditions measured in 1984 in Blue River Reservoir (USACE 1995a).

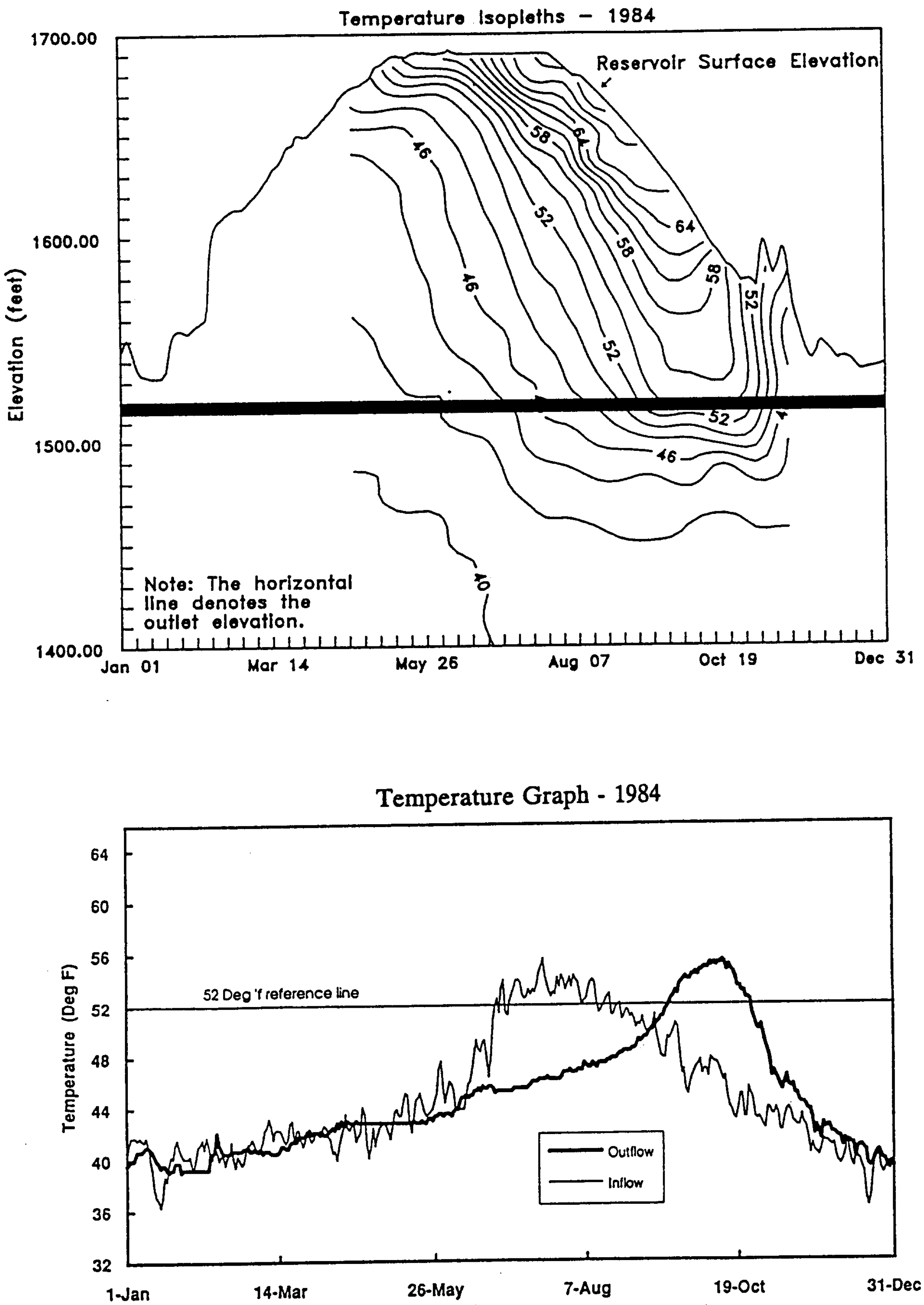


Figure 6-10. Representative thermal conditions measured in 1984 in Cougar Reservoir (USACE 1995a).

between December and May (Hansen 1988). Operation of Leaburg Dam has had a significant effect on instream flows and the ability of the Willamette Project facilities to alter water temperatures farther downstream (USACE 1995a).

Target water temperatures have been recommended by the USFWS, ODFW, and NMFS for the McKenzie River system (Table 6-11). Under existing conditions, the target temperatures are missed on an average annual basis by 3.1°C on the South Fork, 3.0°C on the Blue River, and 0.85°C on the mainstem McKenzie near Vida. Meeting these target temperatures throughout the year requires withdrawal of the warmest water available in the pools. Tributary inflows to Blue River Reservoir are warmer than inflows to Cougar Reservoir. There is relatively little cold water carryover in Blue River reservoir and it warms in the spring more quickly than Cougar Reservoir. Blue River Reservoir accounts for approximately 43 percent of the total warm surface water available within 16 feet of the surface (defined at maximum conservation pool) in both projects for meeting the target water temperatures (USACE 1995a).

Under existing conditions, cooler water temperatures in the late spring and summer impede upstream migration of spring chinook salmon and the growth of native trout, including bull trout. Warmer fall/winter temperatures accelerate egg incubation and fry emergence of spring chinook, and subjects the salmon fry to unfavorable conditions such as high flows and scarce food, which leads to their poor survival (USACE 1995a).

Temperature Effects on Spring Chinook Salmon

Upstream passage of adult chinook salmon at Leaburg Dam appears to be controlled by water temperature. Most upstream migration past the dam has been determined to occur when water temperatures reach or exceed 11.1°C. Upstream migration continues until the water temperature becomes too warm (see general criteria in Table 6-9). Delays in spring migration could result in fish not reaching spawning areas. Fish may hold in deep pools in the mainstem and tributaries before making a final migration to spawning areas in the fall. Effects of the two projects appear to cause delay during mid- to late May, when temperatures exceed the 11.1°C threshold (USACE 1995a).

Spring chinook have been determined to be delayed in their upstream migration at the mouth of the South Fork McKenzie because of cold water temperatures. Experimental releases of warmer waters from the surface of Cougar Reservoir induced migration into the South Fork (USACE 1995a).

Table 6-11. Ranges of target water temperatures (ºC) in the McKenzie River basin for the Willamette temperature control project (USACE 1995a).

Location[1]	**Category**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
SFMR	Max	5.0	5.0	5.0	6.1	8.9	12.8	17.2	17.8	14.4	10.6	7.2	5.0
	Min	3.9	4.4	4.4	5.0	6.7	10.6	13.9	15.0	12.2	9.4	6.7	4.4
BR	Max	5.0	5.0	5.0	6.1	8.9	12.8	17.2	17.8	14.4	10.6	7.2	5.0
	Min	3.9	4.4	4.4	5.0	6.7	10.6	13.9	15.0	12.2	9.4	6.7	4.4
MR	Max	4.4	6.1	6.1	7.2	8.9	11.1	13.3	13.3	11.7	8.3	7.2	6.1
	Min	4.4	6.1	5.6	6.7	8.3	9.4	11.1	11.7	10.6	8.3	7.2	6.1

[1] SFMR – South Fork McKenzie River, RM 3.9 (Rainbow gage), temperature data Oct 1955-Sep 1963.
BR – Blue River, RM 8.5, temperature data Oct 1963-Sep 1967.
MR – McKenzie River, RM 47.7 (near Vida), temperature data Oct 1961-Sep 1963.

Delays in upstream migration caused by temperature regime changes may have influenced shifts in the distribution of chinook salmon spawning from above to below Leaburg Dam, causing some spawning habitat upstream of Leaburg Dam to remain unused. Recent surveys have indicated that good quality, unused spawning habitat above Leaburg Dam is abundant, with little apparent change from historic conditions (USACE 1995a).

Spawning activity does occur above Leaburg, primarily during September and is about 95 percent complete by September 30. Distribution of spawning activity above Leaburg Dam is estimated to be 60 percent above the South Fork, 10 percent in the South Fork, and 30 percent in the mainstem McKenzie. Prespawning mortality is estimated to be 5 percent above the South Fork, 23 percent in the South Fork, and 18 percent in the mainstem, and has been attributed in part to water temperature effects of the Blue River and Cougar projects (USACE 1995a).

Chinook salmon spawning in the McKenzie River subbasin normally begins in early September, peaks in mid- to late September, and ends by mid-October. Embryos incubate for 65 to 80 days with most fry emerging in February to March under natural temperature conditions. In the South Fork McKenzie River, however, fry emergence occurs as early as December because the warmer water released from Cougar Dam in the late fall and early winter accelerates egg incubation. Sampling of fry emergence has indicated that emergence occurs approximately 180 days after spawning in the mainstem McKenzie River above the South Fork McKenzie River, 131 days below, and 86 days in the South Fork McKenzie River (USACE 1995a). Chinook salmon spawning activity is limited in the Blue River below the dam (ODFW 1990e) because of the lack of suitable habitat (including before the dam was built; McIntosh et al. 1995). In general, accelerated egg incubation results in earlier than normal fry emergence, which reduces fry survival because environmental conditions in the winter are not favorable for fry growth or survival (USACE 1995a).

Temperature Effects on Introduced Winter Steelhead

Introduced winter steelhead in the McKenzie River subbasin spawn mostly in the Mohawk River (see Section 5.3.7), and thus significant temperature effects are generally not encountered. Effects have consequently not been evaluated for steelhead, but have been for native rainbow trout, which are closely related. Similar effects could be expected for any steelhead that did spawn downstream of Cougar or Blue River dams. This information may be pertinent to the expansion and recovery of winter steelhead in the Willamette Basin.

Juvenile growth rates in the South Fork McKenzie River and Blue River are likely to be reduced compared to the mainstem because of reduced water temperatures resulting from the Willamette Project. Differences would likely be most pronounced during low flow conditions. Research into trout growth in reservoirs with hypolimnion releases similar to Cougar and Blue River indicate that growth is also influenced by decreased diversity of aquatic insect populations when temperatures are uniformly colder, daily and/or seasonal fluctuations are lacking, and waters are enriched with nutrients (USACE 1995a). These conditions likely exist in the South Fork and Blue rivers downstream of the projects, and to a lesser extent in the mainstem below the South Fork.

Temperature Effects on Bull Trout

Data on temperature requirements for bull trout indicate that this species requires colder water than other salmonid species (Table 6-9). Temperature effects of the Willamette Project are likely to occur during some parts of the year. Table 6-12 lists representative water temperatures in the mainstem and South Fork McKenzie rivers. Comparisons with temperature criteria in Table 6-9 indicate that optimal temperatures can be exceeded for the three life history stages most likely to be affected by the Willamette Project in the McKenzie River subbasin.

Table 6-12. Current mean daily temperatures in the South Fork McKenzie River below Cougar Dam, and in the mainstem McKenzie River downstream, during months important to the different life history stages of bull trout that might use those reaches (USACE 1995a).

Bull Trout Life History Stage and Relevant Time Period	**Range of Current Mean Daily Temperatures (°C)**	
	South Fork McKenzie River	**McKenzie River Below South Fork McKenzie River**
Adult Migration (July-September)	11.1-14.4	7.8-11.1
Spawning (September-October)	12.2-16.7	10.0-13.3
Juvenile Growth (Year round)	4.4-16.7	4.4-13.3

Spawning and egg incubation periods begin in the fall and would be the most impacted by current, with-project water temperatures. Under natural conditions, spawning and egg incubation begin at a time when water temperatures would be naturally cooling. However, in the mainstem and South Fork McKenzie River, temperatures are warming because of reservoir releases. The range of current water temperatures is roughly 7 to 11°C warmer than optimal for bull trout. However, it is likely that bull trout spawning downstream of the Willamette Project locations was extremely limited because better habitat was available upstream, and currently there is none. Water temperatures are currently not conducive to bull trout spawning below Cougar Dam. Limited to no bull trout spawning habitat exists in Blue River below the dam (McIntosh et al. 1995), and water temperatures may be unfavorable there (Figure 6-9).

Water temperatures below Cougar and Blue River dams could adversely affect juvenile bull trout. As for the case of juvenile winter steelhead, juvenile bull trout growth rates could be reduced because of reduced temperatures influencing their food supply in the South Fork McKenzie River. Warmer temperatures during the fall could lead to avoidance by juvenile and adult bull trout. Water temperatures below Cougar Dam and in the mainstem McKenzie River can be suboptimal during the fall, but are generally within the avoidance criteria range for adult bull trout (Tables 6-9 and 6-12). Summer and fall water temperatures are less suitable in the Blue River (Figure 6-9).

6.1.2.2.4 Temperature Effects Specific to the Middle Fork Willamette River Subbasin

The construction and operation of federal projects in the Middle Fork Willamette River subbasin have influenced the temperature regimes downstream of each facility in much the same way as have other Willamette Project facilities. Studies have been conducted on temperature effects below Hills Creek and Dexter dams, but not Falls Creek Dam. Currently, reaches between Dexter and Hills Creek dams are not used by spring chinook salmon. However, the possibility exists that spring chinook salmon may be reintroduced above Lookout Point Dam in the future, at which time temperature effects would become important (USACE 1997). Recent efforts to reintroduce bull trout to the upper reaches of the subbasin (Seims 1997) mean that bull trout could also be potentially affected by temperatures below Hills Creek Dam in the near future.

Temperature Effects Downstream of Fall Creek Dam

No pre-project temperature data exist for Fall Creek Dam. Water temperatures are influenced downstream of the dam by releases of lower-elevation reservoir waters. Seasonal temperature patterns below Fall Creek Dam are similar to temperature patterns seen below the projects in the Santiam and McKenzie subbasins; waters are cooler in the spring, and warmer in the fall. The decreases in spring temperatures may contribute towards shifting of spawning areas further downstream in the mainstem Middle Fork Willamette River, where increased predation on fry and juveniles may occur. Warmer fall releases from Fall Creek Dam likely lead to reduced incubation time and premature emergence (ODFW 1990f).

Temperature Effects Downstream of Hills Creek Dam

Releases from Hills Creek Dam influence the temperature regime all the way downstream to Lookout Point Reservoir. In general, water temperatures are cooler than historic in spring and summer, and warmer in fall and winter. Figure 6-11 depicts the effects that the reservoir has on water temperatures. Inflow and outflow temperatures are similar during the period from January to April. Reservoir releases become colder than inflows beginning in May. While the peak inflow temperatures reach approximately 15.6°C in late July, the peak outflow temperatures lag behind and reach a lower maximum of approximately 14°C three months later in October. While average daily inflow temperatures begin to exceed 11.1°C in early June, releases from Hills Creek Dam do not reach this migration threshold temperature until early September. A potential three month delay in adult migration created by this thermal alteration could prevent reintroduced chinook salmon from reaching high quality spawning habitat in the more important spawning tributaries (USACE 1997).

Outflow temperatures remain significantly higher than inflow temperatures throughout the fall, winter and well into spring (Figure 6-11), which could cause premature emergence of chinook salmon fry from redds constructed in the mainstem Middle Fork Willamette River. However, habitat surveys between Hills Creek Dam and Lookout Point Reservoir indicate that the reach is not well suited to spawning and most spawning activity would occur in tributaries (USACE 1997). The maximum difference between inflow and outflow temperatures has occurred in summer when average outflow temperatures have been as much as 6.1°C cooler than inflow temperatures. During the fall, average outflow temperatures have been as much as 5.6°C warmer than inflow temperatures. Average outflow temperatures have been as much as 1.7°C warmer than inflows in the winter, and up to 2.8°C cooler in the spring (USACE 1997).

Temperature data collected below the North Fork (approximately 12 miles downstream of Hills Creek Dam) before and after dam construction (Figure 6-12) indicate that changes to the natural temperature regime decrease substantially in the downstream direction because of the moderating effect of tributary inflows. Comparison of Figures 6-11 and 6-12 indicates that temperature differences have not been as strong as occur directly downstream of Hills Creek Dam. Average water temperatures have been cooler than historic in the summer by as much as 3.3°C, and warmer in the fall by as much as 2.2°C. During the adult migration period in the spring, the time that the crucial temperature of 52°F is reached has remained about the same between the post- and pre-dam periods (Figure 6-12).

The thermal alteration above Lookout Point Reservoir, particularly above the North Fork of the Middle Fork Willamette River, could adversely affect reintroduction efforts of spring chinook salmon above Lookout Point Dam. The thermal alteration may delay adults from migrating into Salt Creek and Salmon Creek, tributaries that contain a significant fraction of good quality spawning habitat in the upper subbasin. Temperatures generally do not reach 11.1°C at the confluence of the mainstem and Salmon Creek until August, although in some years that may occur as early as June. Adult chinook salmon could probably migrate with minimal delay to the North Fork of the Middle Fork of the Willamette River because the water temperature at the confluence of the North Fork and the mainstem reaches 11.1°C roughly in mid-June. Further, the thermal alteration may delay adults from moving into an adult collection facility located downstream of Hills Creek for collection and transport of the adults over the dam into habitat above Hills Creek.

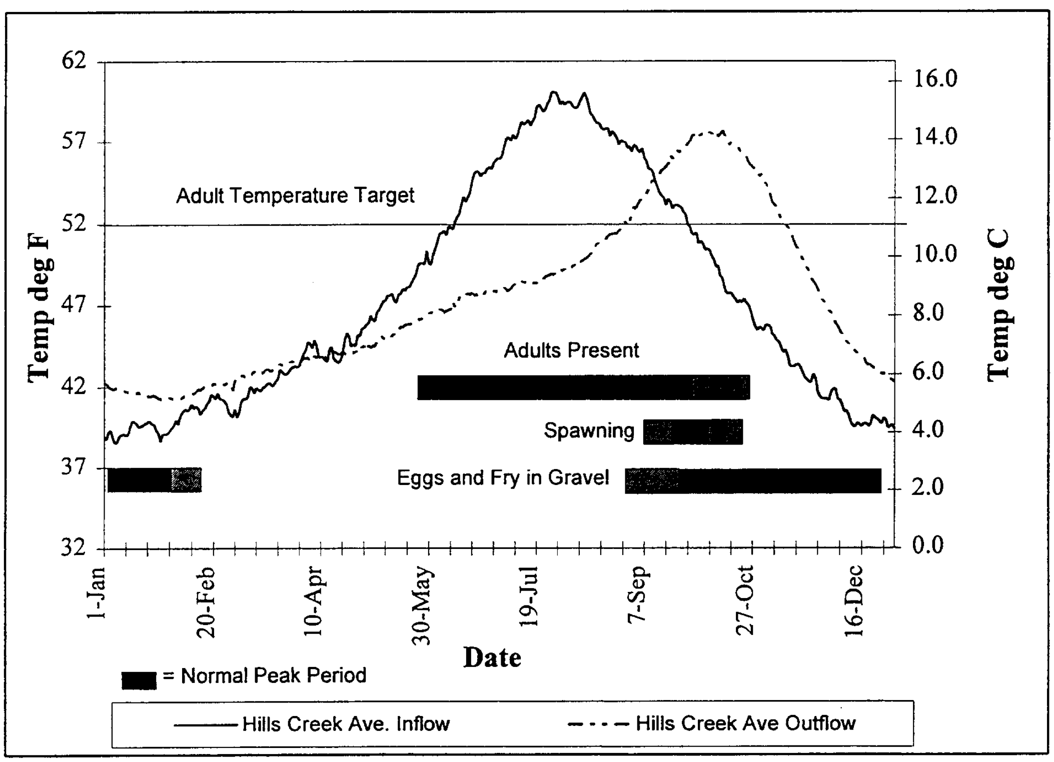


Figure 6-11. Average daily water temperatures measured at Hills Creek Reservoir, Oregon, 1960-1987, and general chinook salmon life stage periodicities (USACE 1997).

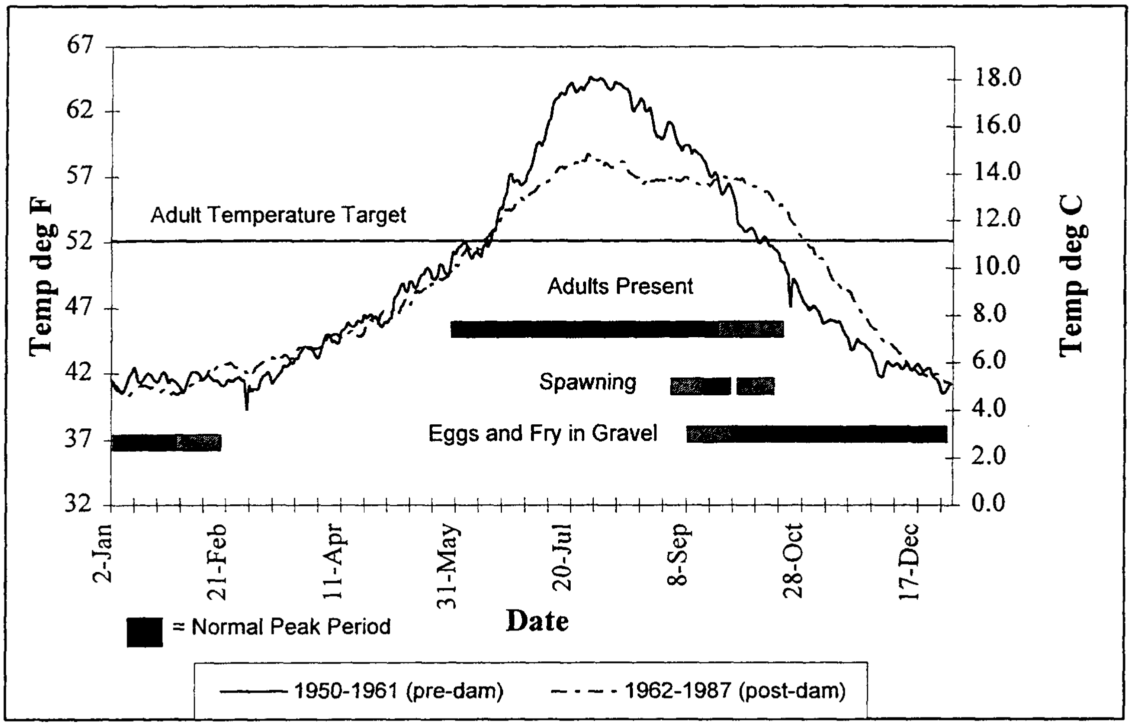
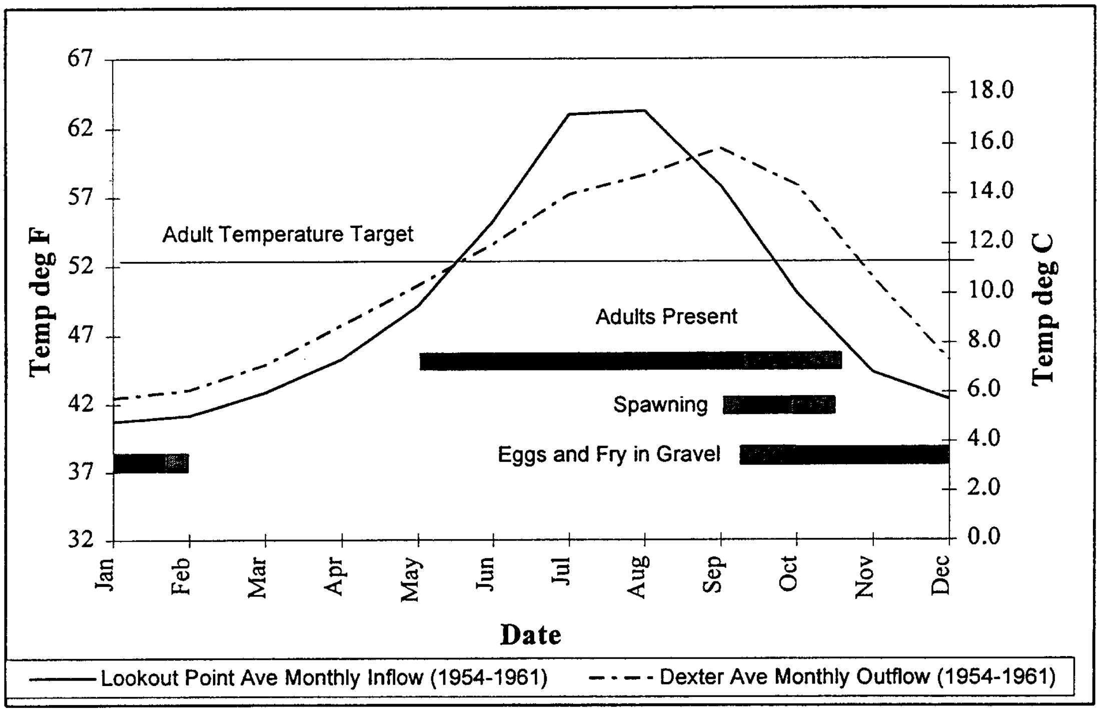


Figure 6-12. Average daily water temperatures measured in the Middle Fork Willamette River, Oregon, thirteen miles below Hills Creek Dam, before (1950-1961) and after (1962-1987) its construction, and general chinook salmon life stage periodicities (USACE 1997).

On the other hand, average daily water temperatures below Hills Creek Dam (which are cooler than natural temperatures during the summer) are suboptimal for adult and juvenile bull trout during the late summer and early fall (Figure 6-11; Table 6-9), limiting suitable bull trout habitat during the summer and fall to the area above Hills Creek Reservoir. Occasionally, temperature maxima could exceed adult bull trout stress thresholds.

Temperature Effects Downstream of Dexter/Lookout Point Reservoir

Figure 6-13 shows the effects that construction of the Lookout Point/Dexter and Hills Creek Projects have had on the water temperature regime below Dexter Dam. The similarity between the two plots indicates that effects downstream of Dexter reflect the influence of Lookout Point Reservoir primarily, because there was only minor change observed in the measured temperature trends after Hills Creek Dam was constructed. Lookout Point Reservoir effectively filters out any effect of Hills Creek on water temperature below Dexter Dam, with the possible exception of late spring-early summer (Figure 6-13).



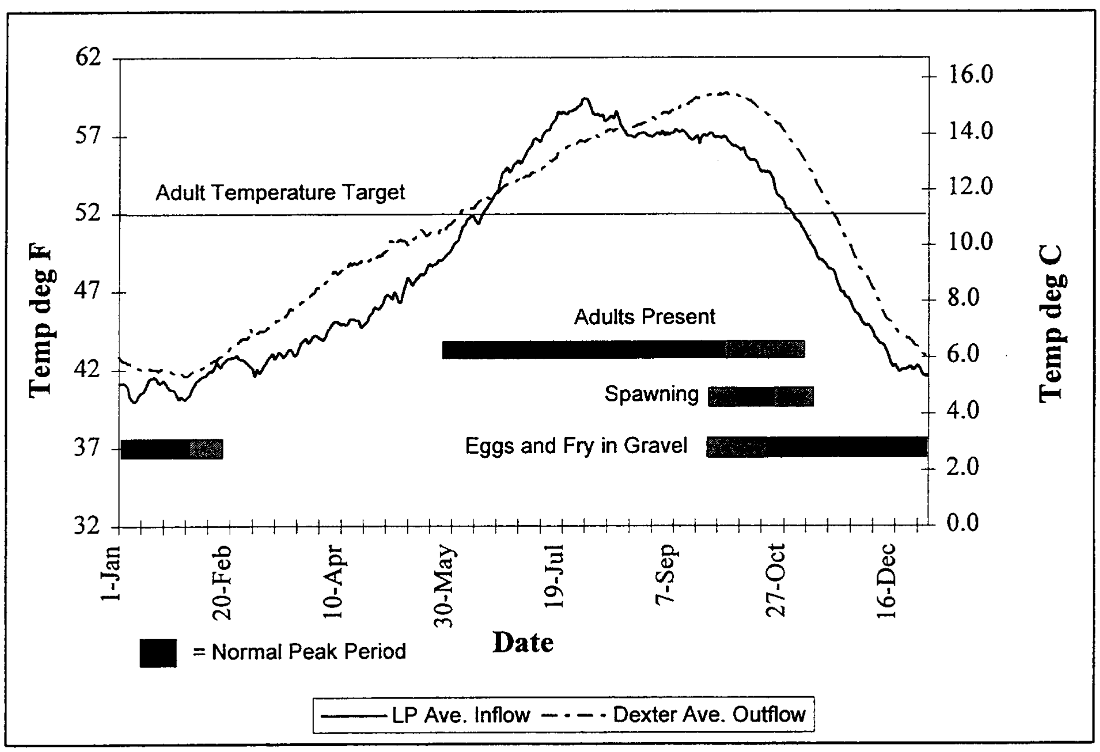


Figure 6-13. Monthly (top) and daily (bottom) average water temperatures in the Middle Fork Willamette River, Oregon, measured above Lookout Point Reservoir and below Dexter Dam, before (top) and after (bottom) construction of Hills Creek Dam (USACE 1997). General chinook salmon life stage periodicities are also indicated.

Lookout Point and Dexter reservoirs influence downstream water temperatures most of the year (Figure 6-13). Outflow temperatures are warmer than historic during the fall, winter, and spring months, and colder during the summer months. Inflow temperatures peak in July at about 16.7°C while outflow temperatures peak at about 15°C two months later in September. Inflow and outflow temperatures reach the 11.1°C threshold to upstream migration at about the same time in mid-May, indicating that temperature effects on chinook salmon adult migration are generally not of concern below Dexter Dam. Returns to the Dexter adult collection facility also indicate that a significant thermal influence on migration does not occur below the dam: the peak of chinook salmon adult returns occurs in mid-May as expected and the number of adults returning annually has generally remained strong (USACE 1997).

The release of warmer water in the fall has likely adversely affected spring chinook salmon offspring downstream of Dexter Dam through accelerated embryo development and consequent premature emergence during the winter.

The release of colder water in the spring than occurred historically may adversely affect introduced winter steelhead juveniles. The colder temperatures extend later in the spring and may inhibit emigration timing. Fish that remain in the mainstem longer as a result, may then become subjected to higher summer water temperatures and increased risk of contracting and dying from bacterial infections (ODFW 1990f).

6.1.2.2.5 Temperature Effects Specific to the Coast Fork Willamette River Subbasin

Salmon and steelhead generally did not occur in substantial numbers historically in the Coast Fork Willamette River subbasin. The release of warm water from Cottage Grove and Dorena reservoirs reduces the value of the lower Coast Fork and Row River appreciably for salmonid production. Also, the amount of water released in the fall, which is above natural levels, is often inadequate for salmon migration and spawning (USACE 1982). Reaches above Cottage Grove and Dorena rarely exceed 21°C, whereas temperatures below the dams can exceed this stress threshold and facilitate disease (Table 6-9). Temperatures in excess of 26ºC have been observed commonly in the past below the two dams (e.g., Thompson et al. 1966). Warmwater species are much more abundant than salmonids (ODFW 1990d), indicating an unfavorable temperature regime.

6.1.2.2.6 Temperature Effects Specific to the Long Tom River Subbasin

Water temperatures in the Long Tom River subbasin are generally unfavorable for salmonid production. Temperatures commonly exceed 21°C in the lower reaches below Fern Ridge Dam, and can exceed 26°C (Thompson et al. 1966), which is lethal to salmonids (Table 6-9). These high temperatures strongly favor warmwater species over salmonids (USACE 1982; ODFW 1990d).

6.1.2.3 Other Water Quality Effects

Development of cities and industries along the Willamette River resulted in serious water quality problems throughout the first half of the century because of raw sewage and untreated industrial discharges, including pulp mill and food processing waste. The reaches most heavily affected by pollution were the lower reach of the mainstem from Newberg to the mouth, and the Santiam and South Santiam rivers downstream of Lebanon (USACE 1982). The Willamette Project was implemented in part to augment summer flows, dilute pollutants, and improve the serious water quality problems that existed historically in the Willamette River.

6.1.2.3.1 Dissolved Oxygen in the Willamette River

The operation of the Willamette Project dams has influenced dissolved oxygen concentrations through increased summer flows. Dissolved oxygen saturation is largely influenced by water temperature: warmer water can contain lower concentrations of dissolved oxygen than colder water. Daily and seasonal shifts in temperature result in natural fluctuations of dissolved oxygen concentrations within the Willamette River basin. Flow volume, in relation to a given level of organic input and resulting oxygen demand, can also influence dissolved oxygen concentrations.

Depressed dissolved oxygen concentrations were common in the lower mainstem Willamette River during the first half of this century, as a result of human and industrial wastes that were discharged into the river. These discharges resulted in high levels of bacterial decomposition and respiration, which caused summertime dissolved oxygen concentrations within the lower river to fall below 5 mg/l. One of the largest effects of low dissolved oxygen levels in the river was the preclusion of fish migration (including of species now listed under the ESA) through this "oxygen block." Passage generally did not occur until dissolved oxygen concentrations were greater than about 3.5 to 5 mg/l (Alabaster 1988). In 1944, the formation and lifting of the oxygen block at Sellwood Bridge on the mainstem Willamette River was shown to be influenced by river discharge and water temperature. The formation of oxygen blocks was eventually minimized through implementing primary treatment of domestic and oxygen-consuming industrial wastes (which reduced the oxygen demand in the river by about 30 percent), increasing minimum flows, and reducing water temperatures (USACE 1982).

A 1979 assessment of low-flow dissolved oxygen conditions in the mainstem Willamette River was conducted by the USGS using a calibrated model (McKenzie et al. 1979). The model described conditions under extended low-flow, high-temperature conditions, which represent the maximum periods of dissolved oxygen depletion. Results of the analysis indicated that summertime dissolved oxygen concentrations were influenced most by: streamflow; the initial dissolved oxygen concentration at RM 86.5 (upstream extent of the study); ammonia-nitrogen loading from the Yamhill River; and sediment-oxygen demand in Portland Harbor. A recent study in the lower mainstem Willamette River concluded that the depletion of dissolved oxygen concentrations in the water overlaying the bottom sediment is caused primarily by decomposition of organic matter in the sediments (Cadwell and Doyle 1994). However, in contrast to historical conditions, the sediment-oxygen demand in most reaches were remarkably consistent, having little difference by river mile, and indicating little impact from industrial or municipal point sources of organic material.

In the Willamette River basin today, the period of concern for dissolved oxygen concentrations continues to be the low-flow period during July and August (Pogue and Anderson 1995). During this time, algal biomass is usually at its annual maximum, water temperatures are warmest, and flows are lowest. During low-flow periods, dilution is lowered and water quality is more sensitive to point-source inputs and the daily changes resulting from photosynthesis and respiration of the aquatic biota (Pogue and Anderson 1995). In July and August of 1994, the USGS, in cooperation with the ODEQ collected data to document the spatial extent and diel variability of dissolved oxygen concentrations in selected reaches of the upper Willamette River basin (Pogue and Anderson 1995). Results of the study indicated that only the Coast Fork Willamette River from RM 21.7 to 12.5 and the Willamette River from RM 151 to 141.6 had dissolved oxygen concentrations that fluctuated below the Oregon state standards. The likely cause of the low dissolved oxygen concentrations observed in the mainstem river was determined to be periphyton (attached algae) respiration. Treated sewage effluent was a likely cause of the observed low dissolved oxygen levels in the Coast Fork Willamette River.

Only two streams in the upper Willamette River basin are listed on Oregon's 1998 303(d) list as impaired due to low dissolved oxygen concentrations: Amazon and Coyote creeks, which are both tributaries to the Long Tom River. No reaches in the mainstem Willamette River are included on Oregon's 1998 303(d) list as impaired due to low dissolved oxygen concentrations (Appendix G).

A probable effect of the increased dissolved oxygen levels in the mainstem Willamette River has been changes in the fish community, as a result of low-flow augmentation from upstream reservoirs and basin-wide secondary sewage treatment. Compared with observations of mainstem fish communities in 1945, the river currently supports increased numbers of fish species that are relatively sensitive to low dissolved oxygen levels (Hughes and Gammon 1987). Dissolved oxygen concentrations are also critical to the salmonid eggs and alevins incubating in the gravel substrate, which require dissolved oxygen levels greater than 7 mg/l in order to develop properly (Bell 1991).

6.1.2.3.2 Dissolved Gas Below Willamette Project Dams

Elevated Total Dissolved Gas (TDG) levels likely occur downstream of each Willamette Project facility that discharges water over the spillway. However, the extent of TDG levels and their effects have not been studied or documented extensively downstream of Willamette Project dams. Two studies were identified that specifically addressed this issue.

Most work has been done below Dexter Dam. Monk et al. (1975) measured total dissolved gas levels that ranged between 104.9 and 125.5 percent of saturation within 0.3 miles downstream of the dam. Levels between 109.2 and 112.5 percent were measured 2.3 and 4.6 miles downstream. Levels were also measured during the period of March to June 1998 in conjunction with unscheduled maintenance of the hydroelectric generation facilities (USACE 1998b). That study determined that dissolved gas levels were minimized when spilled water was distributed across all of the spill gates. Study flows ranged between 1,200 and 8,000 cfs. TDG levels measured 2 miles downstream of the dam were generally below 110 percent of saturation, whereas levels measured within the tailrace area ranged between 108.6 and 121.5 percent downstream of the turbine outlet works, and between 107.3 and 119.0 percent downstream of spill gate number 7 on the left bank. However, on-site observations made during the study of fish caught along the left bank and fish in the Dexter holding ponds did not indicate the occurrence of gas bubble disease (USACE 1998b).

Fewer data exist below the other dams, and it is unknown whether dissolved gas concentrations adversely affect listed species. Dexter has the lowest elevation difference between spillway crest and tailwater (24 feet; see Chapter 2), and it is possible that effects may be less pronounced there than below the other facilities, with the exception of Fern Ridge Dam, which has a similar magnitude elevation difference (25 feet). Effects of TDG are unlikely there should any listed fish species happen to be present (unlikely).

Big Cliff and Foster dams also have relatively low elevation differences (53 and 72 feet, respectively), but that could be enough to result in adverse effects since TDG levels below Dexter were at or above 110 percent of saturation. Foster would be more likely to have an adverse effect because fish are trapped at the base of the dam, whereas the Minto fish weir blocks passage to the base of Big Cliff Dam. Monk et al. (1975) measured a TDG level of 129.2 percent of saturation in the tailrace area of Foster, 115.8 percent 1.2 miles downstream, and 113.3 percent 3.5 miles downstream. The levels in the tailrace area were high enough that adverse effects could occur to listed fish species that stack up at the base of the dam if sufficient spill were to occur then. Levels were below 110 percent downstream of Wiley Creek. In contrast, however, sampling in 1979 measured TDG levels less than or equal to 110.6 percent of saturation below spillway number 4 (Buchanan et al. 1993). It has not been determined under what conditions TDG may be a problem at Foster Dam. At Big Cliff Dam, Monk et al. (1975) measured levels that were at 117.9 and 129 percent of saturation within 1000 feet of the dam, and 120.2 percent 2 miles downstream.

Cottage Grove, Dorena, and Fall Creek dams have elevation differences of 97, 115, and 133 feet, respectively. Of these, Fall Creek Dam has the greater potential for adverse effects because spring chinook and winter steelhead are trapped near the base of the dam, whereas use of the Coast Fork Willamette River basin by listed species is limited. Monk et al. (1975) measured levels ranging between 100.6 and 117.0 percent of saturation near the regulating outlets of Fall Creek Dam. Levels were generally at 110 percent and below within 300 feet of the dam and downstream. No data were collected below Cottage Grove or Dorena dams.

The other dams have higher head, with elevation differences ranging between 200 and 452 feet (see Chapter 2). Spill over Detroit and Lookout Point dams likely does not adversely affect listed species because they discharge into their reregulation reservoirs, where listed fish species do not occur. Monk et al. (1975) measured levels ranging between 95.9 and 118.4 percent of saturation between Detroit and Big Cliff dams, and between 96.1 and 124.7 within 1600 feet of Lookout Point Dam.

Spill from Green Peter may have adversely affected downstream migrant juveniles in the past prior to mothballing of passage facilities (see Section 6.1.4.2.2), but likely does not adversely affect listed species presently because they are now generally absent from the Middle Santiam

River basin. Monk et al. (1975) measured levels ranging between 102.5 and 126.5 percent of saturation between the dam and Coal Creek, and between 102.2 and 117.7 below Coal Creek.

Spill over Hills Creek Dam has the potential to adversely affect bull trout originating from reintroduction efforts above the reservoir. Efforts to reintroduce spring chinook salmon below the reservoir would be similarly influenced. Monk et al. (1975) measured levels at 107.4 and 107.7 percent of saturation near the regulating outlet. Although these are below the critical level, it is likely that higher levels occur because of the elevation difference (275 feet) between spillway crest and tailwater.

Cougar and Blue River dams have the greatest potential to adversely influence spring chinook, bull trout, and possibly winter steelhead through elevated TDG levels because their downstream reaches are used most frequently out of all the high head dams operated by the USACE. Monk et al. (1975) measured levels ranging between 97.8 and 124.1 percent of saturation near the base of Cougar Dam, between 99.5 and 115.7 percent approximately 3000 feet downstream, and between 103.4 and 113.5 percent 2.7 miles downstream. Levels below Blue River Dam ranged between 107.9 and 120.4 percent of saturation downstream of Blue River Dam. It is unknown whether adverse effects occur, however.

6.1.2.3.3 Other Water Quality Parameters in the Willamette River Basin

The concentrations of other water quality components, such as metals and pesticides are also a concern in the Willamette River basin. Numerous organic pesticides are present in the largest streams in the Willamette River basin, and some of those pesticides are present at concentrations that approach criteria for the protection of human or ecological health (Anderson et al. 1997). The Willamette Pesticides Project (Phase III), a cooperative effort between the USGS and the ODEQ, studied a representative set of 16 small streams that each drained approximately 10 square miles of primarily agricultural land (Anderson et al. 1997). Each drainage basin was inventoried in detail to obtain the acreage of crop types being grown. The pesticide application rates were calculated from these crop acreage and literature values for application of compounds to each particular crop. Four sites draining primarily urban land also were chosen in order to provide a comparison between agricultural and urban land uses. Water-quality sampling was done five times between April and November, 1996--twice in the spring to coincide with spring storms, once during summer low flow, and twice in the fall during fall storms.

A total of 36 pesticides (29 herbicides and 7 insecticides) were detected basinwide that likely find their way into the Willamette River. The five most frequently detected compounds were the herbicides atrazine (99% of samples), desethylatrazine (93%), simazine (85%), metolachlor (85%), and diuron (73%). Although the transport of contaminants to the stream is related to discharge and the amount of runoff, correlations between discharge and pesticide concentration were poor (Anderson et al. 1997). Concentrations of pesticides have been determined to be generally greater in small streams than in larger streams (Anderson et al. 1997).

Concentrations of trace elements, such as chromium, copper, lead, and zinc, in the Willamette River basin were collected between 1992 and 1994 (Anderson et al. 1996). The highest trace-element concentrations generally were found at urban sites that receive a large portion of their runoff from industrial areas. Mercury concentrations in water are generally below the detection limit of most analyses. However, even low levels of mercury in the environment can be toxic to aquatic animals and the organisms that prey on them, because mercury concentrations are bioaccumulated. Analyses of fish tissue collected in the Willamette River basin indicated that detrimental levels of mercury are found in Cottage Grove Reservoir, Dorena Reservoir, the Coast Fork Willamette River, and the mainstem Willamette River (ODEQ 1998). All of the sampled fish that contained high levels of mercury were resident fish, such as northern pikeminnow, largemouth bass, and smallmouth bass. None of the sampled fish that contained high levels of mercury were listed species.

The 1998 Oregon 303(d) list includes the mainstem Willamette River, from the mouth upstream to the Calapooia River, as being impaired due to significantly higher incidences of skeletal deformities than those measured in either the upper river or reference site (ODEQ 1998). These deformities could be a result of water quality problems.

The USACE Willamette Project dams influence suspended sediment levels within the reservoirs and downstream of the dams. The impoundments can act as settling basins for suspended sediments originating upstream, which could result in reduced turbidity downstream of the dams. Alternatively operation of the dams can increase inputs of fine sediments as a result of increased shoreline erosion and mass wasting. Operation of the dams can also increase downstream channel erosion, which can result in increased turbidity. Relationships between suspended sediment load and stream discharge downstream of the dams were not different during pre- and post-reservoir periods (Wentz et al. 1998). However, measurements of suspended sediment in reaches downstream of the dam sites indicate that sediment sources have changed since completion of the dams, which suggests that the amount of sediment trapped by the reservoirs has been balanced by increased erosion of downstream sediment sources (Wentz et al. 1998).

6.1.2.3.4 Water Quality Effects Specific to Santiam River Subbasin

The effects of Detroit, Big Cliff, Foster, and Green Peter dams on the listed species from altered water quality are relatively unknown beyond temperature. None of the reaches within the North, South, or mainstem Santiam River subbasins are included on the 1998 ODEQ 303(d) list for any water quality impairment other than high summertime temperature. Operation of the dams results in summertime flow augmentation in all three rivers. The likely effects of this increased flow are higher or saturated dissolved oxygen levels and dilution of any contaminants in the river using the relatively pristine waters stored behind Detroit and Green Peter dams. These are beneficial effects for listed fish species.

An historical survey conducted in 1940 noted that the South Fork Santiam River, from the mouth of the river to approximately RM 19 (1 mile below the Lebanon bridge), was highly polluted with chemical waste from a paper mill and sewage from the city of Lebanon (McIntosh et al. 1995). Many dead fish were observed and the bottom rubble was covered with a thick gelatinous substance. The paper mill diverted nearly 100 percent of the river flow at certain times of the year. This lower reach of the river also experienced an oxygen block during summer months (USACE 1982). Improved paper pulping processes, secondary wastewater treatment, and summer flow augmentation resulting from the operation of Foster and Green Peter dams have helped correct these water quality problems.

6.1.2.3.5 Water Quality Effects Specific to McKenzie River Subbasin

The effects of Blue River and Cougar dams on listed species from altered water quality are relatively unknown beyond temperature. None of the reaches within the Blue River and South Fork McKenzie River subbasins are listed on the 1998 ODEQ 303(d) list for any water quality impairment other than high summertime temperature. Releases from the dam are used for summertime flow augmentation in the McKenzie River. The likely effects of this increased flow are higher or saturated dissolved oxygen levels and dilution of any contaminants in the respective rivers using the relatively pristine waters stored behind the two dams. These are beneficial effects for listed fish species.

Flood water discharges result in increased turbidity in Blue River and the South Fork McKenzie River, but it is unknown whether there are any adverse effects resulting from the discharges (USACE 1995a).

In general, water quality in the rivers downstream of the two dams, including the mainstem McKenzie River, are of high quality. There are few pollution discharges to the rivers upstream of Vida, which is located approximately 13 miles downstream of the mouth of the Blue River. The biggest pollution problem in the McKenzie River is from industrial waste discharges lower in the subbasin. Dissolved oxygen levels are consistently high in the mainstem and do not appear to limit fish resources (USACE 1995a).

6.1.2.3.6 Water Quality Effects Specific to Middle Fork Willamette River Subbasin

The effects of Fall Creek, Hills Creek, and Lookout Point dams on listed species from altered water quality are relatively unknown beyond temperature. None of the reaches within the Middle Fork Willamette subbasin are included on the 1998 ODEQ 303(d) list for any water quality impairment other than high summertime temperature. Releases from the dams are used for summertime flow augmentation in the Middle Fork Willamette River and the mainstem Willamette River. The likely effects of this increased flow are higher or saturated dissolved oxygen levels and dilution of any contaminants. These are beneficial effects for listed fish species.

6.1.2.3.7 Water Quality Effects Specific to Coast Fork Willamette River Subbasin

The effects of Dorena and Cottage Grove dams on listed species from altered water quality are relatively unknown beyond temperature. Current water quality concerns for both the Row River and Coast Fork Willamette River subbasins include high mercury levels in fish tissue. Mercury has been found in fish from both reservoirs at levels potentially hazardous to human consumption, and fishing regulations are in place to limit the consumption of these fish. Downstream of the Row River, the Coast Fork River is also impaired by elevated levels of fecal coliform (ODEQ 1999).

Mercury-laden waters enter the reservoirs from the upper watershed, originating from both mining and natural sources. The contribution of mining activities to the mercury problem is relatively unknown. A recent report indicated that a point source, Black Butte Mine contributed amounts of mercury to Cottage Grove Reservoir in excess of mobilization from natural deposits, atmospheric deposition, and use of the metal during processing of gold (Park and Curtis 1997). Juvenile spring chinook reared in the reservoir by ODFW during 1969 through 1976 were believed to have low survival upon entering salt water as a result of accumulated mercury (ODFW 1990d).

It is unknown whether flow release patterns are influencing mercury mobilization and transport downstream. Releases from the two dams are used for summertime flow augmentation in the Coast Fork Willamette River and the mainstem Willamette River. Likely effects of this increased flow include higher or saturated dissolved oxygen levels and increased dilution of contaminants including mercury. These could be beneficial effects for listed fish species, although the amount of benefit reflects the degree to which operations might mobilize sediments containing mercury (unknown).

6.1.2.3.8 Water Quality Effects Specific to Long Tom River Subbasin

The Long Tom River downstream of Fern Ridge Dam is generally turbid (Ely 1981; McIntosh et al. 1995). Limited water quality data exists for the river upstream of the dam. Measurements from an ODEQ macroinvertebrate sampling station near the headwaters at RM 48.5 indicate that the stream condition at this site is moderately impaired (Canale 1999). Water quality impairments from livestock and other agricultural activities are problematic upstream of Fern Ridge Dam. Coyote Creek and Amazon Creek are included on ODEQ's 303(d) impaired waterbody list because of elevated fecal coliform bacteria levels and low dissolved oxygen concentrations from May through October (ODEQ 1998). Industrial activities along Amazon Creek have resulted in degraded water quality from chemical spills in the past (ODFW 1990d). The Long Tom River below the Fern Ridge Dam is included on ODEQ's 303(d) list of impaired waterbodies for elevated temperatures and also for elevated levels of fecal coliform bacteria (ODEQ 1998).

It is unlikely that effects of Fern Ridge Dam on water quality could influence listed fish species, however, because of their absence from the subbasin.

6.1.3 Migration Barriers and Loss of Habitat Above Dams

Dam construction has resulted in substantial reductions in listed species production because of reductions in available habitat. Reduction in population and habitat availability are part of the baseline environmental conditions occurring at the time of listing for Willamette River basin ESU's under the federal ESA. Hatchery propagation and construction of fish passage facilities have been the primary forms of mitigation for habitat losses caused by construction of Willamette Project dams. However, many of the passage facilities have not been as successful as originally anticipated (see Section 6.4), and the mitigation burden has shifted for most streams influenced by the Willamette Project to primarily hatchery production. Construction of the dams has also resulted in the shifting of spring chinook salmon and winter steelhead spawning activity to reaches and tributaries located below the dams, where hydrographic, water quality, and other effects described in other sections of this chapter may occur.

6.1.3.1 Potential Effects Caused by Dam Construction

The creation of an impoundment results in the loss of riverine habitat and the creation of lacustrine habitat. Significant aquatic community shifts can occur as a result, and the change frequently amounts to a loss in habitat quantity for one species and a gain for another. Riverine habitat loss is most important when critical reaches existed previously that were under-represented elsewhere in the channel network. Inundation of critical riverine spawning grounds can result in the most significant impacts because recruitment may be reduced or even eliminated. Alternatively, there may be sufficient spawning habitat available elsewhere but the conditions for rearing may be poorer than existed in the inundated reach, resulting in reduced juvenile carrying capacity or survival.

Physical habitat loss also occurs when the dam poses as a barrier to upstream migration. Unless passage is provided around the structure, entire river stocks of anadromous salmonids can be eliminated because they can no longer return to their spawning grounds and provide for recruitment. The same is true for resident species such as bull trout that use the lower and upper portions of a river system during different life history stages and can no longer migrate upstream. In some cases, the population may find other habitat downstream of the dam, but overall the size of the population will likely be reduced significantly if the majority of its spawning habitat was located upstream. Whether or not the loss is significant to the status and recovery of an ESU depends on the relative proportion of the ESU to which the former population contributed, and on the diversity of other spawning populations comprising the ESU.

Upstream passage of migrating adult anadromous and resident salmonids can be delayed as they search for an appropriate route through a fish ladder or other means facilitating migration. Fish that are migrating upstream in search of spawning habitat may also be delayed when they encounter a dam without passage facilities and have to swim back downstream in search of habitat elsewhere. Delay can result in adverse effects if water temperatures are outside of optimal ranges, or if the delay time is sufficient that critical energy reserves for migration and spawning are used up. In addition, the fish may be stressed, making them more susceptible to disease and predation. Delays may also increase susceptibility to harvest near the dams.

Without fish passage facilities, resident fluvial fish populations may be prevented from moving within their historic distribution range, where the ability to migrate may be an important adaptation facilitating recolonization of areas that have been disturbed significantly. Bull trout metapopulations appear to be particularly dependent on the availability of migration corridors and the existence of a regional population (Rieman and McIntyre 1993; Rieman and McIntyre 1996; Northcote 1997). The fragmentation of bull trout metapopulations may have been a significant influence on Willamette River bull trout populations' ability to maintain themselves (Buchanan et al. 1997).

6.1.3.2 Summary of Lost and Blocked Habitat for Anadromous Salmonids

Table 6-13 lists available spawning habitat estimated by Craig and Townsend (1946) for salmon and steelhead in the upper Willamette River basin prior to the construction of the dams. The numbers in the table are for mainstem habitat only, however, and considerably more spawning and rearing habitat was blocked in the tributaries (Fulton 1968; Fulton 1970). Cottage Grove and Dorena dams were noted by Thompson et al. (1966) to have blocked the better quality spawning and rearing habitat in the Coast Fork Willamette subbasin.

Table 6-14 lists the approximate amounts of habitat lost to inundation by Willamette Project reservoirs, as represented by reservoir length. The actual amounts were slightly greater because of sinuosity of the river channel. It is unknown whether any of the affected river reaches provided special spawning or rearing habitat that controlled population size. Thompson et al. (1966) noted that Foster and Green Peter dams inundated approximately 19 percent of good quality anadromous fish habitat present above the Foster dam site.

6.1.3.3 Barriers to Migration of Anadromous Salmonids

Willamette Project dams may result in delays in migration as adult spring chinook salmon and winter steelhead are turned around and forced to search for spawning habitat elsewhere or wait to enter trapping facilities. Winter steelhead returning to below Foster Dam are also delayed prior to collection and transport upstream. It is unknown whether the effect is sufficiently adverse to result in reduced spawning fitness or survival of the adults and their progeny.

6.1.3.4 Effects of Blockages on Resident Fish Species Metapopulations

Fragmentation and isolation of bull trout populations have created a patchwork of remnant populations in the Columbia River basin (63 FR 31674). Self-sustaining populations of bull trout were probably found historically throughout much of the Willamette River basin (Goetz

Table 6-13. Estimated spawning habitat quantities above and below Willamette Project dams, Oregon (Craig and Townsend 1946)

	Lineal Miles Surveyed				**Spawning Area Available (yds^2)**			
Stream	**Below Dam**	**Above Dam**	**Total**	**Percent Above Dam**	**Below Dam**	**Above Dam**	**Total**	**Percent Above Dam**
North Santiam River	66.2	61.1	127.3	48.0	1,875,001	800,778	2,684,779	30.1
South Santiam River	87.7	63.5	151.2	42.0	2,352,539	874,278	3,226,817	27.1
McKenzie River	76.7	103.3	180.0	57.4	3,224,923	1,841,112	5,066,035	36.3
Middle Fork Willamette River	83.6	74.5	158.1	47.1	2,501,145	1,226,140	3,727,285	32.9
Total	314.2	302.4	616.6		9,953,608	4,751,308	14,704,916	

Table 6-14. Approximate miles of river habitat inundated by Willamette Project reservoirs, Oregon (USACE project data).

Dam	Stream	Length of Reservoir (miles)
Big Cliff	North Santiam River	2.8
Detroit	North Santiam River	9.0
Green Peter	Middle Fork Santiam River	10.0
Foster	South Fork Santiam River	3.5
Blue River	Blue River	6.4
Cougar	South Fork McKenzie	6.5
Fall Creek	Fall Creek	10.3
Hills Creek	Middle Fork Willamette River	7.6
Lookout Point	Middle Fork Willamette River	14.2
Dexter	Middle Fork Willamette River	2.8
Dorena	Row River	5.0
Cottage Grove	Coast Fork River	3.0
Fern Ridge	Long Tom River	4.5

1994), but are currently limited to the McKenzie River subbasin (Buchanan et al. 1997). The disruption of historical distributions can increase the risk of extinction of these populations, including especially those members living in marginal or extreme habitats (Rieman and McIntyre 1993). Barriers caused by the Willamette Project dams prevent bull trout from freely migrating between winter refuge areas and summer foraging areas, and prevent gene flow from occurring among the isolated populations. A recent observation of an adult bull trout in the McKenzie River at its mouth (Unthank 1999) suggests that the mainstem Willamette River may have served as a migration route between subbasin populations. A bull trout caught in the Long Tom River in the early 1960s (Goetz 1994) likely originated from another subbasin (because of water quality problems in the Long Tom River) and therefore had to pass through the mainstem Willamette River. This points to the importance of migratory corridors in the basin as a means for population redistribution between spawning, rearing, and adult habitat areas. Construction of the Willamette Project has likely adversely affected bull trout populations by blocking migration routes throughout the system. An interim bull trout conservation guidance document has identified the need to preserve or restore connectivity among bull trout subpopulations and their habitats, as one of the overall objectives for bull trout conservation and recovery (USFWS 1998b).

Bull trout were present historically in the North Santiam River, but the last observation of a bull trout in this river system was in 1945, and the population is considered to be "probably extinct" (Buchanan et al. 1997). If bull trout were able to recolonize the North Santiam, they would likely be limited to tributaries upstream of Detroit Dam due to the cold water requirements of the species and the barriers to migration from the Minto fish weir and the two dams. Although some bull trout fry from the McKenzie River population have been transferred and released into suitable waters within the Willamette River basin, the North Santiam River subbasin was not identified as a recommended location for these recolonization efforts (Buchanan et al. 1997). Therefore it is unlikely that the migration barriers formed by Big Cliff and Detroit dams have or are likely to have an adverse effect on bull trout recolonization in the foreseeable future.

The McKenzie River system contains the last remaining bull trout populations in the Willamette River basin (Buchanan et al. 1997). Fluvial bull trout populations in the McKenzie River system are now comprised of three isolated populations (see Section 4.1.7; Buchanan et al. 1997). These stocks are isolated from each other by Cougar Dam on the South Fork McKenzie River and by Trail Bridge Dam on the mainstem McKenzie River (Buchanan et al. 1997). These two dams adversely affect bull trout migrations. The population in the mainstem McKenzie River includes fish sporadically using the Blue River downstream of the dam (Mark Wade, ODFW, personal communication, April 2000). However, the barrier to bull trout migration caused by Blue River Dam may not have an adverse effect on bull trout recovery in the McKenzie River subbasin because of the limited amount of suitable bull trout habitat and higher summer water temperatures in the Blue River (Figure 6-9; Amy Unthank, USFS, personal communication).

Bull trout were present historically in the Middle Fork Willamette River, but the last confirmed sighting of an adult bull trout was in 1990, and the population is considered to be "probably extinct" (Buchanan et al. 1997). Bull trout fry from the McKenzie River population are transferred and released into the Middle Fork Willamette River subbasin as part of management efforts to expand the distribution of bull trout in the Willamette River basin (Buchanan et al. 1997). If these efforts are successful and a reproducing population is established in the Middle Fork Willamette River, the barriers to bull trout migration caused by Hills Creek Dam and possibly Lookout Point and Dexter dams are likely to adversely affect bull trout recovery in the Middle Fork Willamette River subbasin.

Fragmentation and isolation of fish populations resulting from dam operation has also been observed for resident cutthroat trout in the Long Tom River. In this river, a historically fluvial population of cutthroat trout that reared in the mainstem Willamette and spawned in the Long

Tom River is now isolated into two groups. The population upstream of Fern Ridge Dam now rears in a lake environment and exhibits an adfluvial life history.

6.1.4 Upstream and Downstream Fish Passage Past Dams

Dams and impoundments can influence passage stress and survival of both upstream- and downstream-migrating fishes. As a part of baseline environmental conditions at the time of listing, all Willamette Project dams except Foster Dam have either not had fish passage facilities associated with them, or have facilities that have not been used or usable by upper Willamette spring chinook or winter steelhead for as much as 30 years and more (see Chapter 2), and listed members of these species' ESUs are no longer located above those dams. Thus, most Willamette Project dams do not currently result in at-dam passage effects on listed Upper Willamette salmon and steelhead.

This section presents information relevant to the potential effects of the Willamette Project on fish passage if listed fish were to be re-introduced above the reservoirs. The information presented is provided primarily to facilitate the evaluation of alternative recovery options, rather than to assess potential effects of current Willamette Project operations with two exceptions: effects of fish passage facilities at Foster Dam on listed salmon and steelhead in the South Santiam River and effects of Cougar Dam on bull trout metapopulations located above and below the dam on the South Fork McKenzie River are examined relative to current operations.

Unlisted hatchery salmon and steelhead have been, or are currently, trapped and transported to critical habitat above several Willamette Project reservoirs. The current status of these hatchery introductions is discussed where they occur. Tentative plans of the state of Oregon include restoring runs of one or more listed species above most dams where natural production of the listed species historically occurred (ODFW 1988b). Each Willamette Project facility is examined regarding potential upstream and downstream fish passage effects irrespective of whether any hatchery fish are currently transported to areas upstream of the facility.

6.1.4.1 Potential Passage Effects

Adult fish migrating upstream may be adversely affected as they move through adult passage and collection facilities. Fishways, trapping facilities and activities, and hauling fish upstream above dams can result in physical injury to the fish. Fall-back increases the potential for adverse effects. Adults that pass hydroelectric dams and fall back through turbine intakes incur mortality, injury, or severe stress. The slow water of the impoundment above the dam may delay upstream migration or may speed it up, depending on whether the fish is disoriented or continues moving purposely through a slower-velocity medium. Resident adult salmonids may be more susceptible to adverse effects than anadromous because they are smaller in size. Trucking of fish can cause stress or death when dissolved oxygen concentrations in the hauling tank drop because of fish respiration (Petts 1984; Mighetto and Ebel 1994; NMFS 1995a).

Downstream-migrating juvenile anadromous salmonids are subject to a much greater range of adverse effects than adults. Impoundments result in significant migration delay, which interferes with the smoltification process and increases exposure to disease and predation. If the delay is sufficient, some juveniles may remain in reservoirs without reaching the ocean. Juveniles are more likely to bypass fish collection facilities than adults because they are purposely moving in the downstream direction and are smaller. Fish passing through the turbines are susceptible to mortality and descaling. The extent of direct turbine mortality depends on the type of turbine and its operational characteristics; some turbines effect relatively little direct mortality. However, descaling can be a significant indirect source of mortality because it can make fish more susceptible to disease and predation. Other sources of mortality during downstream passage include rapid pressure changes as juvenile passes through the intake and turbine, predation on disoriented juveniles in the tailrace, and gas bubble disease below spillways and hydroelectric facilities affecting nitrogen supersaturation. Early bypass systems and fish-handling facilities resulted in greater injury and descaling than today, but all fish can still incur physical injury as they pass over spillways, through fishways, turbine intakes and conduits, etc., through velocity, pressure, striking, and abrasive forces. Juveniles that are transported around dams can also experience stress and mortality (Petts 1984; Mighetto and Ebel, 1994; NMFS 1995a; Spence et al. 1996; Alden Research Laboratory, 1997).

Willamette Project dams with hydroelectric facilities use either Francis or Kaplan turbines to generate electricity. Francis turbines are typically installed at higher head projects than Kaplan units. Each type is associated with specific mortality characteristics (Alden Research Laboratory 1997). Mortality rates of juvenile salmonids passing through Francis and Kaplan turbines have been determined to be approximately 20 percent and 12 percent, respectively (EPRI 1992).

The turbine runner entrance appears to be a region of greatest fish mortality within Francis turbine units, where wicket gates, blades, and peripheral speed are possible contributors to fish injury. Wicket gates determine the quantity and direction of the flow through the runner entrance. Fish mortality has been correlated with higher peripheral speeds and greater wicket gate openings, but not plant operating head. Fish mortality appears to increase with fish size, possibly because of strike-related injury (EPRI 1992).

The area between the blade tips and the throat ring appears to be a region of greatest fish mortality within Kaplan turbine units, where fish are likely ground between the blades and the throat ring. Peripheral speed and plant operating head have not been correlated with fish mortality (EPRI 1992). Average survival of smolts passing through Kaplan turbines has been estimated to be approximately 87 percent (Bickford and Skalski 2000).

Fish injury is reduced when turbines operate at highest efficiency (1995 USACE Turbine Passage Survival Workshop in Portland). Efficient turbine operation is associated with minimum cavitation, a process whereby gas bubbles form within the flow field as local pressures are reduced rapidly to vapor pressure. The bubbles implode with great force when local pressures increase rapidly again and cause shock waves that may result in fish mortality. Highest efficiencies that can be achieved are 85 to 95 percent of the rated load by Francis turbines, and 65 to 70 percent of the rated load by Kaplan turbines (Alden Research Laboratory 1997).

Shear injuries can occur when a fish experiences a large velocity gradient over its body length. The extent of shear injury is influenced by the size of the fish relative to the shear zone, by the pressure gradient, and by the angle at which the fish is swimming within the shear zone. Velocities in a turbine can range from zero to 120 ft/s, with gradients of 30 ft/s. Kaplan turbines generally have lower velocity gradients than Francis units, but can be associated with significant velocity shear zones that are created by vortices shedding off the turbine runner and by leakage through gaps between moving and stationary components. Francis turbines can be associated with significant velocity shear zones that are created by a vortex that forms downstream of the turbine runner ("draft tube swirl") (Alden Research Laboratory, 1997).

Rapid pressure changes can cause fish injury and mortality and are related to the head at which the turbine is operated. Kaplan units usually have lower differential pressures than Francis units because of their being installed at low head projects. This may be a reason why Kaplan units are usually associated with lower fish passage mortality rates (Alden Research Laboratory, 1997).

6.1.4.2 Santiam River Subbasin

6.1.4.2.1 Passage at Detroit and Big Cliff Dams

There is currently no natural production of spring chinook salmon or winter steelhead above Detroit and Big Cliff dams because upstream migration is blocked completely. Bull trout may have used the subbasin historically but are thought to be extinct (Buchanan et al. 1997). There are no fish passage facilities at either dam, and upstream migrating salmonids are blocked and trapped at the Minto weir located approximately 2 miles downstream of Big Cliff Dam. Adult spring chinook salmon and winter steelhead have not been released above the two dams to spawn naturally because neither dam has juvenile fish passage facilities. Spring chinook and winter steelhead trapped at the Minto facility are spawned and their offspring are reared at the Marion Forks Hatchery, located upstream of Detroit Reservoir. They are released as smolts downstream of the Minto fish rack. Significant, adverse water temperature and disease problems have not been noted for adult fish trapped at the Minto facility.

The lack of natural production of listed species above Big Cliff Dam means that there are presently no adverse effects related directly to passage of listed species upstream or downstream of Detroit and Big Cliff dams.

The absence of fish passage facilities for adults or juveniles at either dam would likely influence reintroduction efforts upstream. There are currently no plans to do so. Such plans would have to consider the possibility of mortality as downstream migrants pass through the turbines, regulating outlets, or over the spillway, and are thus exposed to the potential sources of injury and mortality described in Section 6.1.4.1. Studies of passage success at Big Cliff Dam indicated that juveniles would experience a turbine strike mortality of approximately 10 percent (Alden Research Laboratories 1997).

6.1.4.2.2 Passage at Green Peter Dam

No listed fish species are currently found above Green Peter Dam. Potential effects of passage at the dam are currently moot because of predation problems in the reservoir. However, they could be important if efforts to restore spring chinook and winter steelhead runs above the dam begin and the predation problem is lessened (Buchanan et al. 1993). In that event, upstream and downstream migrants would be subject to the following effects.

Upstream Passage

The adult upstream passage facilities have been generally unsuccessful. Cold water releases in the fish ladder have generally caused returning adult spring chinook salmon and winter steelhead to avoid entering the fishway, thereby delaying their migration. Tests conducted between 1983 and 1987 indicated that approximately 46 percent of adult hatchery steelhead released in Foster Reservoir reached the Green Peter fishway. Radiotagged fish have been observed to reach the Green Peter tailrace without a significant delay in their migration, but avoided the entrance to the fishway and often strayed into the South Santiam River instead. Studies determined that it took six days on average for steelhead released in Foster Reservoir to enter the Green Peter adult trap; steelhead reached the Green Peter Dam tailrace in approximately two days, and the remainder was associated with fish looking for a suitable upstream passage route (Buchanan et al. 1993).

Downstream Passage:

Prior to "mothballing" of the downstream passage facilities in 1988, fewer than 2 percent of presmolts and 50 percent of smolts released in and above Green Peter Reservoir migrated past Green Peter Dam. Adults released above Green Peter Reservoir were widely distributed and appeared to spawn successfully, but very few of their progeny made it to the dam (Buchanan et al. 1993).

Migration rates of smolts were slow because water velocity is slow within the reservoir. Outmigrating juvenile salmon and steelhead generally experienced a three-week delay when migrating through Green Peter Reservoir compared to juveniles migrating through Foster Reservoir (ODFW 1990c; Buchanan et al. 1993). The reservoir shoreline is long and meandering and there are a large number of predators within the reservoir (USACE 1995b). Studies were conducted between 1980 and 1986 by ODFW in which steelhead smolts were released in different locations and their migration rates were estimated. Between 35 and 90 percent of steelhead smolts released in a tributary (Thistle Creek) flowing into the reservoir made it successfully below the dam. Between 1 and 24 percent of smolts released within the reservoir, and approximately 24 to 38 percent of smolts released in the forebay, passed successfully to below the dam. Overall reservoir migration and dam passage survival rates were generally higher for earlier years and declined with time as predator population numbers increased. Rates were determined for juvenile chinook salmon to be between 75 and 84 percent during 1968-1969, and between approximately 34 and 57 percent for steelhead in 1968-1970 (FCO, 1971). A biologically sustainable success rate of 70 percent has been suggested by ODFW as a target for the Green Peter project (Wade et al. 1987; Buchanan et al. 1993).

There was no delay in migration once the juveniles reached the entrance to the downstream passage facility at the dam. Moreover, predators were not noted to be present in great abundance near the facility entrance. Those smolts that were able to reach the collection facility generally passed successfully downstream, although descaling and other injuries were noted that could influence survival of some fish (Buchanan et al. 1993). As described in Chapter 2, corrosion within the juvenile transport pipe resulted in some injury and possibly mortality, but that problem was corrected while the facility was still operational.

6.1.4.2.3 Passage at Foster Dam

Upstream Passage

The upstream passage facilities at Foster Dam have generally been found to function adequately (USACE 1995b). However, disease problems in the holding ponds have resulted in holding only a small number of adult spring chinook salmon in the ponds, and the majority of returning chinook are presently made to hold in the dam tailrace instead until the passage facility is operated and the fish are collected and transported to the South Santiam Hatchery. Disease problems associated with passage interruption are likely adversely affecting spring chinook salmon adults.

Fish trucked and released above Green Peter and Foster dams were noted to have low spawning success rates when released into the reservoir instead of tributaries. Stress during dam passage was also thought to be a reason for low spawning success (FCO 1971). Adult chinook and steelhead released directly into the Foster Dam forebay were less successful in their upstream migration than fish that were hauled and released upstream. Many adult winter steelhead released into the forebay were observed to fall back over the dam or pass through the turbines (Buchanan et al. 1993). Those that survived then had to move through the fish passage facility a second time, increasing the potential for injury. Presently, listed winter steelhead are trapped at the dam, and trucked and released only in the South Santiam River upstream of Foster Reservoir. Hatchery-supplemented spring chinook salmon were, but are not presently, trucked upstream of Foster Reservoir.

Downstream Passage

Juvenile downstream migrants must pass through either the Kaplan turbines or the spillway gates and thus may incur injury. Currently, juvenile downstream passage facilities include a slotted weir that is positioned at the surface of the forebay to guide surface oriented migrants. Buchanan et al. (1993) reported that freefall spill and reservoir levels held at 614 NGVD during April and May provided the best conditions for winter steelhead smolt migration from Foster Reservoir, based on the results of adult return ratios.

Overall, fish passage efficiencies during the spring have been estimated to be between about 50 and 70 percent for spring chinook salmon and between about 6 and 61 percent for winter steelhead (FCO 1971). The fish must sound between six and fifteen meters to pass through the turbines or the spill gates, but can be reluctant to do so (ODFW 1990c). Smolts passing over the spillway do not appear to suffer injuries, and gas supersaturation has been determined to not be a problem (Buchanan et al. 1993). Smolt mortality from passage through the turbines has been estimated at approximately 10 percent (FCO 1971). Experiments determined that 8.9 to 12.0 percent of downstream migrating hatchery juveniles experienced mortality as they passed through the turbines (Wagner and Ingram 1973). The primary cause of mortality appeared to be strike-related. Other experiments have indirectly indicated a mortality rate as high as 23 percent (Buchanan et al. 1984).

Migration of chinook salmon smolts produced naturally upstream of Foster Reservoir does not appear to be delayed during the fall and winter when the reservoir is drawn down; juvenile steelhead generally do not migrate during that period (FCO 1971). Both species' outmigrations are delayed in the spring when filling of Foster Reservoir begins in April. Migration delay of winter steelhead smolts from Foster Reservoir is thought to delay their arrival timing to the lower Willamette River, increasing their risk of contracting temperature-related diseases and experiencing physiological stress (Buchanan et al. 1993; ODFW 1998).

6.1.4.3 McKenzie River Subbasin

6.1.4.3.1 Passage at Blue River Dam

There are no fish passage facilities at Blue River Dam; upstream migrating adults are not trapped and released upstream. Efforts to mitigate for the lack of fish passage facilities have involved planting of chinook salmon fry in the reservoir. Approximately 200,000 hatchery fry have been stocked annually since 1984, and adult chinook have been observed below the dam since 1986 (ODFW 1990e). However, the stocked fish experience high mortality rates when they pass the dam as smolts (USACE 1995a). Downstream migrants must pass through the regulating outlets, or through the two spill gates and drop approximately 230 feet in elevation. Passage survival appears to be low. Chinook salmon fingerlings stocked in Blue River Reservoir in 1983 were later found to be growing into smolts. Several smolts originating from Blue River Reservoir were found dead or injured at Leaburg Dam in 1986, apparently as a result of migrating through Blue River Dam during evacuation of the reservoir. In another study, approximately 76 percent of 5,000 smolts migrating out of the reservoir in the fall of 1989 were observed to be dead or dying (ODFW 1990e). The lack of downstream passage facilities would therefore adversely affect the progeny of any adult spring chinook salmon released above the dam.

6.1.4.3.2 Passage at Cougar Dam

Upstream Passage

As described in Section 2.5.2, the adult passage facilities designed and constructed as part of the Cougar Dam facility do not work properly, in large part because of water that is too cold for adult attraction. The failure of the upstream passage facilities has adversely affected the upstream passage of adult spring chinook native to the South Fork McKenzie River to spawning habitat above Cougar Reservoir. This in turn has adversely affected bull trout above the reservoir because a source of nutrients (chinook carcasses) and food (chinook eggs, fry, and juveniles) has been cut-off. Presently, some natural production of spring chinook salmon occurs above Cougar Dam through releases by ODFW, of adults from excess hatchery stock above the reservoir. The salmon are being released to provide the missing carcasses and spawner progeny for bull trout production and consumption, respectively.

Downstream Passage

Downstream passage facilities constructed at Cougar Dam were not used after the first few years of operation because spring chinook salmon smolts were determined to experience high mortality as they attempted to migrate downstream (Ingram and Korn 1968; ODFW 1990e). Collection and survival of juveniles passing the dam was unsatisfactory despite good rearing conditions in the reservoir. Studies using marked hatchery fish showed that the juvenile collection efficiency ranged from about 8 to 17 percent. Tests conducted in 1965 and 1966 indicated that between about 30 and 40 percent of the fish were found dead in the collection facility and more fish were found dead in the stilling basin (Ingram and Korn 1968).

Studies were conducted again recently to assess downstream mortality, between November 1998 and March 1999. Juvenile chinook passage was monitored through the turbines and regulating outlets (ODFW 1999c). It was estimated that 14,000 juvenile chinook migrated through the regulating outlet and between 1500 and 4000 juveniles migrated through the Francis turbine. Mortality rates were estimated at about 7 percent for the turbine route and 32 percent for the regulating outlet route. Mortality rates were also determined to increase with fish size. The present fish passage facilities are therefore likely to adversely affect listed juvenile spring chinook salmon migrating downstream.

Several radio-tagged adult bull trout released above the dam have been found downstream after passing through the facility. These fish varied in their condition; one fish was found to be in good shape, whereas another showed signs of injury (J. Ziller, ODFW Springfield, personal communication, August 1999).

6.1.4.4 Middle Fork Willamette River Subbasin

6.1.4.4.1 Passage at Fall Creek Dam

Upstream Passage

Winter steelhead and spring chinook are trapped at Fall Creek Dam. Most adults are taken to the McKenzie and other hatcheries, but some are released upstream of the reservoir. The upstream migrants could be adversely affected in the trapping facility through abrasion, mechanical injury, and stress, and may experience delay in migration and disease when water temperatures are unfavorable. Trucking and release upstream could adversely affect adults through mechanical injury low dissolved oxygen levels.

Downstream Passage

Naturally produced, downstream migrant chinook salmon and winter steelhead must pass through the regulating outlets of Fall Creek Dam and may incur injury or mortality. The juveniles are offspring of adults that are trapped at the dam and released upstream. The greatest source of injury and mortality is thought to occur as the fish pass under the regulating outlet gates, because fish released downstream of the gates generally do not incur significant injuries (Downey and Smith 1992). Injury and mortality rates generally increase with head and flow rate through the regulation outlets. Studies conducted in 1991 determined that of 1,000,000 smolts released into the reservoir, 250,000 survived to be passed downstream through the regulating outlets, out of which 163,000 migrants survived. It was also estimated that the "mothballed" downstream passage fish horn system resulted in a mortality rate of approximately 68 percent, and that the survivors were in poor condition, with a majority receiving severe head and eye abrasion (Downey and Smith 1992). Lowering the reservoir water levels in September and October was determined to decrease the head and flow through the outlets, with lower mortality rates.

Until recently, hatchery chinook salmon fry were released into Fall Creek Reservoir, where they reared to smolts in four or five months. The ODFW terminated the rearing of chinook in the reservoir in 1998 because of the high downstream passage mortality and now rear the salmon to smolt size in the hatchery. Approximately 100,000 smolts are now released annually below Fall

Creek Dam. Much higher survival is anticipated since the migrants do not have to pass through the regulating outlets.

6.1.4.4.2 Passage at Hills Creek Dam

There are no upstream or downstream fish passage facilities at Hills Creek Dam. Dexter Dam presently blocks upstream migrant chinook salmon and steelhead from reaching Hills Creek Dam. Fish trapped at Dexter Dam are not released upstream presently, but studies have been conducted recently of the feasibility of restoring anadromous runs upstream of Dexter (USACE 1997). Water temperature issues would need to be resolved first above Lookout Point Reservoir, however.

Recently stocked bull trout (ODFW 1997b) and the offspring of excess anadromous hatchery fish released occasionally above Hills Creek Dam by ODFW would have to negotiate the dam when they undergo migration. The fish have to pass either through the two Francis turbines, through the regulating outlet, or over the spillway, and would be susceptible to the types of injuries and mortality sources described in Section 6.1.4.1.

6.1.4.4.3 Passage at Lookout Point and Dexter Dams

There are no upstream or downstream migrant passage facilities at either Lookout Point or Dexter dams. Dexter Dam presently blocks upstream migrant chinook salmon and steelhead from upstream spawning areas. Fish trapped at Dexter Dam are not released upstream presently, but studies have been conducted recently of the feasibility of restoring anadromous runs upstream of Dexter (USACE 1997). Water temperature issues would need to be resolved first above Lookout Point Reservoir, however.

Upstream migrating spring chinook salmon and winter steelhead adults are trapped below Dexter Dam and are kept in a holding pond there until they are transported to the Willamette Hatchery for spawning. Spring chinook adults often exhibit head wounds and fungus in the holding ponds that likely originate from passage at Willamette Falls. Some adults are transported upstream by ODFW to a release point located above Hills Creek Reservoir. Fish that are blocked from migrating upstream by the barrier presented by Dexter Dam have suffered “severe” losses in the past from disease associated with warm water temperatures (Hutchison et al. 1966b).

After rearing for about 14 months, some of these juveniles are transported to the rearing pond and raceways below Dexter pond for release. Because the rearing pond and raceways lie below

Dexter Dam, these fish do not have to travel over spillways or through turbines. If downstream migrants are ever present in Lookout Point or Dexter reservoirs as a result of upstream stocking, they must generally pass through the turbines and would be susceptible to the types of injuries and mortality sources described in Section 6.1.4.1. Bull trout potentially migrating during cooler winter months would also have to pass predominantly through the turbines.

6.1.4.5 Coast Fork Willamette River Subbasin

6.1.4.5.1 Passage at Dorena Dam

There are no provisions for fish passage at Dorena Dam. Bull trout are not present above Dorena Dam and neither spring chinook salmon nor winter steelhead are released upstream. Very few adult anadromous fish enter the Coast Fork Willamette and Row rivers presently. Those that do are primarily hatchery strays.

6.1.4.5.2 Passage at Cottage Grove Dam

There are no provisions for fish passage at Cottage Grove Dam. Bull trout are not present above Cottage Grove Dam and neither spring chinook salmon nor winter steelhead are released upstream. As indicated for Dorena Dam, very few adult anadromous fish stray into the area, and the majority that do are hatchery fish.

6.1.4.6 Passage at Fern Ridge Dam in the Long Tom River Subbasin

There are no provisions for fish passage at Fern Ridge Dam. Neither bull trout, spring chinook salmon, nor winter steelhead are present in the Long Tom River system.

6.1.5 Geomorphic Effects

Dams have a significant effect on sediment transport and channel geomorphology, where more than 90 percent of the suspended load, and all bedload, may settle out and be trapped within an impoundment. The net effect is that the channel becomes sediment starved and may not be able to meet the river's transport capacity between the dam and lower gradient, aggradational reaches located further downstream. Dams also interrupt the supply of large woody debris to downstream reaches. Changes in channel morphology and bed character may occur that may adversely affect habitat for listed fish species downstream of the dams. Relatively few studies have been conducted of the geomorphic changes that have occurred in the Willamette system, however. Most work has concerned the mainstem Willamette River, and changes caused by other human activities.

6.1.5.1 Potential Geomorphic Effects

After dam construction, the channel bed usually becomes coarser and more armored, resulting in loss of potential spawning habitat, and possibly changes in aquatic macroinvertebrate production and community composition. Armoring reduces the frequency that the bed is disturbed, resulting in long term fine sediment impacts to reproductive success of spawning salmonids.

In some cases, the river bed degrades after dam construction, resulting in a more incised channel. Effects include increased velocities, which results in reduced refuge habitat during high flows, and loss of floodplain connectivity. In other cases, the channel banks may erode in response to reduced sediment loading from upstream, resulting in a wider, shallower channel. Channel width may increase by as much as 100 percent. Changes are most dramatic within ten years or so of dam construction, and may continue more slowly for a much longer period (Williams and Wolman 1984; Petts 1984). Either case may be associated with reductions in overbank flooding and floodplain-related habitat quality and quantity.

Shallower, wider channels may be more susceptible to warming than narrower channels, have reduced velocities, be comprised of fewer pools, and exhibit reduced habitat complexity and structure associated with banks and large organic debris. Reduced velocities may lead to decreased habitat capacity for territorial species. Many species are reliant on pools and habitat structure for cover and feeding.

Changes in sediment and hydrologic regimes can result in channelization because of the encroachment of riparian vegetation (Dykaar and Wigington 1999). Reduced flood flows and increased bed stability facilitate the growth of perennial vegetation closer to the channel margin. The bank protection afforded by the established vegetation can reduce active channel width and bank erosion, resulting in incision and more channelized conditions such as increased velocities (Perkins 1993; Dunne and Dietrich 1979).

Floodplain and aquatic habitat formation and maintenance can be impaired by flood control. Important floodplain-connected fish habitat may be reduced in quality and quantity, and even accessibility when overbank flow is prevented. The functions of floodplains related to water quality and long-term water storage can also be impaired or precluded when flooding is prevented. Floods facilitate recruitment of new wood and gravel from uplands and pool scouring, which can contribute to habitat quality and quantity (Schroeder and Savonen 1997). Recruitment of large woody debris is also reduced in the absence of floods that result in channel migration or avulsion. In combination with the interrupted downstream transport of LWD, reduced recruitment can lead to a decline in in-channel wood, as existing material decays or is moved downstream without being replaced (Abbe and Montgomery 1996).

Another effect of the altered hydrologic and sediment transport regime has likely been a change in the accessibility of off-channel habitats. Side channels or sloughs accessible only at higher flows may become disconnected from the mainstem, preventing use by salmonids (Fuerstenberg et al. 1996). Conversely, the increased duration of moderate and summer flows by dam operations under the right circumstances could help keep side channels wetted or connected to the main channel; it is unknown whether this may be the case for the Willamette River and its tributaries.

Bank protection works can reduce habitat complexity and quantity depending on the design and fish species. Bank protection and channelization reduces or eliminates input of woody debris and nutrients from the riparian zone. Flood control and bank protection can also modify habitat quantity and quality through channelization and elimination of side channel and slough habitat. Bank protection works can result in lower rearing habitat value for juvenile salmonids (Peters et al. 1998). Natural banks generally have a higher percentage of their area in wood, cobble and boulder, aquatic plants or undercuts than hydromodified banks, and juvenile fish abundance has a high correlation with wood or other types of cover (Beamer and Henderson 1998).

6.1.5.2 Geomorphic Effects Observed Generally in the Willamette River Basin

Willamette Project dam construction and the associated reduction in peak flows had an immediate effect on channel geomorphology throughout the entire length of river downstream. The primary, initial effects observed in the Willamette River basin included stabilization of formerly active channels and encroachment of vegetation onto bar surfaces (USACE 1980). These changes exacerbated the loss of geomorphic complexity that occurred as a result of channel clearing and construction of levees and revetments (Sedell and Froggatt 1984; Benner and Sedell 1997). The amount of habitat area available to juvenile salmonids and other fish species was reduced substantially. As much as 75 percent of the original shoreline of the mainstem Willamette River was lost through the closure or elimination of marshes, multiple channels, and oxbow lakes (Sedell and Froggatt 1984). Much of the development of the Willamette Valley has led to channelization, and loss of roughly half the side channel habitat that was available historically (Benner and Sedell 1997). Studies from other large river systems in the Pacific Northwest indicate that disconnection of off-channel habitat from the mainstem has the potential to reduce salmonid production by as much as 90 percent, even though these habitats represent only a fraction of the channel network (Beechie et al. 1994). The loss of such habitat may have contributed to the decline of spring chinook salmon and winter steelhead trout above Willamette Falls, and continues today to influence recovery potential.

Changes caused by gravel transport interruption were probably most dramatic immediately below each dam within the first ten years following construction (Williams and Wolman 1984). However, geomorphic effects are far from done and will continue into the future. As the rivers continue to transport gravel downstream, the effect of the reduced sediment supply will continue to extend downstream and may not be evident for a number of years. Studies of gravel bedded rivers elsewhere in the Pacific Northwest suggest that the effects of changes in gravel-supply may “move” downstream at a rate of approximately 3,000 to 5,000 feet per year in undammed rivers (Perkins 1999). The assumption was made in this BA that the downstream sediment transport rate is less in regulated rivers. An estimate of 2,000 feet per year was assumed to be appropriate for evaluating the extent of the effects of reduced sediment supply in the Willamette system. The actual distance will vary spatially within and between rivers with slope and distance downstream from each dam, and with flow regime and flood history.

6.1.5.3 Mainstem Willamette River

The effects of reduced gravel supply from tributary streams have not yet been documented within the mainstem Willamette to any significant degree, but may occur within the next several decades (see Section 5.1). As the effects of the reduced gravel supply begin to influence the mainstem, they may exacerbate the general trend toward channel incision that is currently attributable to channelization and gravel mining (Klingeman 1973). Continued or accelerated channel incision could isolate the few remaining off-channel habitats present in the mainstem Willamette River. Since current Willamette Project operational flows appear to be insufficient to create new off-channel habitat in the mainstem Willamette River since completion of the last dam in 1968 (Landers et al. 1999), future effects of the Willamette Project on gravel transport in the mainstem Willamette River are likely to adversely modify critical habitat.

Future coarsening of the mainstem substrate could occur, although such effects may take longer than in the tributaries because the average bed slope of the mainstem is much smaller. In general, substrates located throughout most of the mainstem are currently considered unused by listed species for spawning (see Section 5.1). Potential spawning areas that do exist could become unsuitable in the future because of armoring.

6.1.5.4 Santiam River

The effects of reduced sediment supply were not evident in the Santiam River by the early 1980s (Klingeman 1981), and may not influence habitat conditions there until some time around 2066 with continued operation of the Willamette Project, assuming effects travel downstream at a rate of 2000 feet per year. Current channel incision rates attributed to local instream gravel mining and channelization, and bed degradation in the mainstem Willamette River (Klingeman 1973; Klingeman 1981) may increase, which could substantially alter future fish habitat in the mainstem Santiam. The most likely effect would be a coarsening of the channel bed, and continued channel incision that would isolate off-channel habitats currently connected to the mainstem at high flows. The effects of reduced peak flows have probably already resulted in encroachment of riparian vegetation and a narrowing of the channel. The effects of these changes on listed salmonids may be similar to those described for the North and South Santiam rivers below.

6.1.5.4.1 North Santiam River

The North Santiam River consists of three morphologically distinct reaches downstream of Big Cliff Dam: a canyon reach (RM 50 to RM 57), a narrow alluvial valley reach (RM 50 to RM 38) and an alluvial reach (RM 30 to RM 11). Based on the assumption that the impacts of disrupted sediment supply extend downstream at a rate of approximately 2,000 feet per year, the entire canyon reach may have responded to the reduction around 1972. Since this reach is bedrock controlled, degradation and changes in morphology were probably minimal. It is likely that most sediment stored behind obstructions and in low velocity channel marginal areas have been transported downstream by 1999. Continued operation of Detroit and Big Cliff dams will prevent refill of these transient storage sites, which will limit the availability of spawning gravel for winter steelhead and spring chinook salmon, the species most likely to utilize this habitat.

The channel gradient decreases downstream of RM 50 to the confluence with the Little North Santiam at RM 38, and narrow alluvial deposits border the river. The reduced sediment supply has probably resulted in a coarsening of the bed and possibly channel incision within this reach (see Section 5.2). Effects of reduced sediment supply on fish habitat could have begun around the early 1970s, and likely continue today. Greatest effects of gravel supply reduction may continue over the next decade, assuming effects travel downstream at an average rate of 2000 feet per year (see Section 6.1.5.2).

The Little North Santiam River continues to contribute sediment to the North Santiam River downstream of RM 50, which helps reduce the effects of interrupted supply from above Big Cliff Dam. Some bed coarsening and channel incision may occur in the future that could reduce the amount of useable spawning substrates. The effects of reduced sediment supply have probably occurred only relatively recently in the alluvial reach.

Riparian encroachment and loss of large woody debris have probably been most pronounced in the narrow alluvial reach between RM 50 and RM 38. Downstream of RM 38, large floods still occur on occasion and the Little North Santiam serves as a source of both large woody debris and sediment.

Further reductions in channel width are unlikely in the North Santiam River because riparian vegetation communities have likely reached equilibrium with the post-dam flow regime by now. However, the continued suppression of large woody debris recruitment may continue to limit development of pool and side channel habitat. Interruption of downstream wood transport and recruitment through bank erosion may also have reduced nutrient inputs, an effect that could continue to influence salmonid habitat in the North Santiam River.

The current distribution of side channel habitats in the North Santiam River has not been quantified. However, Big Cliff and Detroit dams have probably caused a reduction in the amount of accessible side channel habitat in the narrow alluvial reach, and may continue to do so.

6.1.5.4.2 South Santiam River

The South Santiam River flows through a narrow alluvial valley for approximately 17 miles (RM 37 to RM 20) downstream of Foster Dam before entering the wide alluvial valley of the Willamette. Based on the assumption that the impacts of disrupted sediment supply extend downstream at a rate of approximately 2,000 feet per year (see Section 6.1.5.2), effects of the dam are assumed to extend downstream currently to approximately RM 25. Since the river downstream of the dams is alluvial with an easily erodible bed, degradation and a coarsening of the substrate are the expected response to dam construction. However, the dramatically reduced transport capacity and continued sediment inputs from tributary streams may have moderated these effects somewhat. Bed coarsening resulting from the reduced sediment supply is expected to continue to extend downstream; however, the effects of channel degradation may become less pronounced as the distance from the dam increases because of decreasing channel gradient and increasing inputs from tributaries and bank sources. It is possible, however, that the amount of spawning habitat for salmonids will decrease in the future.

Reduction in peak flows in the South Santiam River has probably already resulted in the encroachment of riparian vegetation onto formerly active bar surfaces and into off-channel habitats no longer connected to the river by frequent overbank flows. These effects, in combination with channel incision resulting from reduced sediment supply may have reduced the amount of off-channel habitat available to juvenile salmonids. Further reductions in channel width are unlikely as riparian vegetation communities should have reached equilibrium with the post-dam flow regime by this time. However, the continued suppression of large woody debris recruitment could limit future development of pool and side channel habitat.

6.1.5.5 McKenzie River

The McKenzie River downstream of Blue River and Cougar dams consists of four morphologically distinct reaches: a narrow valley filled with glacial moraine and outwash material, a deeply incised canyon, a narrow alluvial valley reach and a wide alluvial floodplain reach. Based on the assumption that the effects of disrupted sediment supply extend downstream at a rate of approximately 2,000 feet per year (see Section 6.1.5.2), the glacial and canyon reaches between the confluence with the South Fork McKenzie and Leaburg Dam would be expected to respond to the reduction within the next twenty years.

The effects of peak flow regulation are believed to have been greatest downstream of Leaburg Dam (see Chapter 5 for additional details). Ligon et al. (1995) documented a gradual progression of channel form from formerly braided reaches of the lower McKenzie River to single-thread reaches, as flood peaks were reduced and riparian encroachment occurred. Mid-channel bars and islands were gone by 1990 in the reaches studied by Ligon et al. (1995), suggesting that further reductions in channel width are unlikely; riparian vegetation communities should have reached a new equilibrium by now under the post-dam flow regime. It is unclear how much of the effect may be attributable to Leaburg Dam, which has partially altered sediment transport rates downstream because of upstream trapping and associated deposition from slope reduction.

Klingeman (1973) noted that the bed of the McKenzie River had degraded near its mouth by approximately 3 feet between 1945 and 1965, and by another 3 feet in the next six years. The cause was suspected to be factors other than construction of Blue River and Cougar dams (Klingeman 1973). It is unlikely that effects of the dams resulted that far downstream within that short a time after construction. Because much of the reach between Leaburg Dam and the South Fork McKenzie River is bedrock controlled, and sediment continues to enter the mainstem from upstream tributaries, future degradation and changes in morphology have likely occurred at a relatively slower rate.

Blue River and Cougar dams will continue to trap sediments and spawning substrates that would otherwise be available for salmonids downstream in later years. Ligon et al. (1995) proposed that spawning habitat may be limited currently in the mainstem McKenzie River because more females were observed than redds, and they suspected that redd superimposition was occurring. However, chinook salmon spawner-recruit data suggest that spawning habitat limitation is not occurring (see Section 4.1.1.2), and there appears to be abundant spawning habitat present elsewhere in the McKenzie River that is not being used currently. It has yet to be determined whether spawning habitat availability will be significantly altered in the future.

6.1.5.6 Middle Fork Willamette River

The Middle Fork Willamette River downstream of Dexter Dam flows through an alluvial valley for approximately 17 miles before joining the Coast Fork Willamette to form the Willamette River. Based on the assumption that the impacts of disrupted sediment supply extend downstream at a rate of approximately 2,000 feet per year, effects of the dam are expected have influenced the entire reach downstream of Dexter Dam by now. Since the reduction in sediment supply has been so great, and the river downstream of the dams is alluvial with an easily erodible bed, degradation and a coarsening of the substrate are believed to have occurred. Given that there has been sufficient time for the entire reach to respond to the reduced sediment supply, future changes are expected to be smaller. The bed armoring may have reduced the amount and quality of spawning gravel, and this reduction will probably continue to affect salmonids in the Middle Fork Willamette River mainstem.

Encroachment of riparian vegetation onto formerly active bar surfaces and into off-channel habitats no longer connected to the river by frequent overbank flows has probably also occurred by now. The resultant narrower channel, in combination with incision resulting from reduced sediment supply may have reduced the amount of off-channel habitat available to juvenile salmonids and Oregon chub in general.

Further reductions in channel width are unlikely as riparian vegetation communities are expected to have reached equilibrium with the post-dam flow regime by this time. However, the continued suppression of large woody debris recruitment will likely limit future development of pool and side channel habitat.

6.1.5.7 Coast Fork Willamette River

The Coast Fork Willamette River downstream of Cottage Grove Dam, and the lower Row River below Dorena Dam flows through an alluvial valley for approximately 21 miles before joining the Middle Fork Willamette to form the Willamette River. Based on the assumption that the impacts of disrupted sediment supply extend downstream at a rate of approximately 2,000 feet per year, effects of the dams are expected have influenced the entire length of river downstream of both Cottage Grove and Dorena dams. Since the reduction in sediment supply has been large, degradation and a coarsening of the substrate are believed to have occurred. Given that there has been sufficient time for the downstream reaches to respond to the reduced sediment supply, future changes are expected to be small. Bed armoring may have reduced the amount and quality of spawning gravel. However, since the extent of salmonid spawning below the two dams has been small historically and presently, it is unlikely that reduction in spawning habitat availability caused by bed armoring will influence salmonid reproduction significantly in the Coast Fork Willamette River subbasin for the foreseeable future.

Encroachment of riparian vegetation onto formerly active bar surfaces and into off-channel habitats no longer connected to the river by frequent overbank flows has been likely completed by now. The resultant narrower channel, combined with possible incision resulting from reduced sediment supply, may have reduced the amount of off-channel habitat available to salmonids. Continued suppression of large woody debris recruitment should continue to limit future development of pool and side channel habitat.

6.1.5.8 Long Tom River

The Long Tom River flows across the western edge of the Willamette Valley for approximately 26 miles downstream of Fern Ridge Dam before joining the Willamette River. The river flows across deep, fine-grained alluvial and lacustrine deposits, and unlike other tributaries has a bed composed primarily of sand and silt. Williams and Wolman (1984) found that travel rates for the leading edge of degradation in sand-bedded rivers moved downstream more quickly than has been observed in gravel bedded rivers, at rates ranging from 0 to 5,000 feet per year, and sometimes more. Assuming that the impacts of disrupted sediment supply extend downstream at a rate of approximately 3,000 feet per year, the effects of Fern Ridge Dam are estimated to have reached the mouth by around 1985. Since the river downstream of the dam has a bed composed primarily of sand and silt, channel incision was the most likely response (changes in bed elevation do not appear to have been studied in this reach). Although channel incision could have contributed to the isolation of formerly connected off channel habitats, channelization appears to be the predominant cause (ODFW 1990d). Further channel incision (if it occurs) would probably progress at a much slower pace than immediately following closure of the dam (Williams and Wolman 1984).

No salmonids are known to have utilized the Long Tom River historically for spawning (McIntosh et al. 1995), but the slough-like conditions could be suitable as winter refugia for juvenile salmonids living normally in the mainstem Willamette River. Levee construction and isolation of side channel habitats have likely reduced the value as off-channel habitats to both salmonids and Oregon chub.

6.1.6 Predation, Exotic Aquatic Animal Species, and Community Species Shifts

6.1.6.1 Potential Effects

Reservoirs can provide extensive habitat for predators of listed species. Although the predators may not target the species of concern, they can be present in sufficient numbers that their overall impact is large. Potential effects of predation are greatest in the Willamette River basin for migrating fish, and particularly downstream-migrating anadromous salmonids, which become more susceptible to predation because the water in the impoundment is effectively no longer flowing. Riverine water velocities provide fewer habitat opportunities for large numbers of predators, and increase the probability that a migrating fish will pass by a predator location safely. Environmental conditions within the impoundment may also stress listed species and make them more susceptible to predation (e.g., through increased water temperature).

Exotic animal and plant species may: compete with native species occupying similar ecological niches for food and habitat; compete with the food source of a native species; prey on native species; and modify, reduce, or eliminate habitat for other species. An introduced species can outcompete native species directly absent changes to the latter's environment simply because they are better adapted or more adaptable, or because environmental conditions become more favorable after dam construction.

Non-native fish and other vertebrate and invertebrate species may be introduced to reservoirs or river channels by authorized fisheries agencies (e.g., stocking of brown trout), unauthorized actions (e.g., release of bait fish or favored sportfishing species), or by accident (e.g., flooding of aquaculture ponds or movement through constructed water conveyance channels). Alternatively, they may be effectively "introduced" from populations living further downstream. This can occur in response to changes in temperature regime below an impoundment that creates more favorable habitat conditions for non-native species. Changes in flow patterns below an impoundment may likewise afford upstream passage for non-native species around a former barrier.

Environmental changes upstream and downstream of dams in the Willamette River basin may facilitate increased densities of native predators or competing species if environmental conditions become more favorable for them. Native northern pikeminnow, redside shiners (*Richardsonius balteatus*) and numerous sculpin (*Cottus* spp.) species may compete for food and habitat with, and prey on, salmonid fry and Oregon chub in the Willamette River system (Wydoski and Whitney 1979). Redside shiner populations have been noted to increase and juvenile resident and anadromous salmonid populations decrease with average summer water temperatures (Chapman et al. 1994). Sculpin populations are more resilient to increased loading of fine sediments and can tolerate higher water temperatures than salmonids (Wydoski and Whitney 1979).

Non-native brook trout were stocked historically until the late 1990s in many of the high elevation lakes that drain to streams in the Willamette River basin containing bull trout. Bull and brook trout, two related char species, are thought to directly compete for limited habitat resources. Brook trout tend to be more aggressive than bull trout and may displace bull trout from optimal foraging areas. In addition to direct competition for resources, brook trout pose an additional threat to bull trout since the two species are capable of interbreeding (Leary et al. 1983, Scott and Crossman 1973, Markle 1992) and the hybrid offspring typically do not reproduce (Leary et al. 1991). Brook trout tend to eventually replace bull trout when interbreeding occurs, as a result of differences in their life history strategies (e.g., brook trout mature earlier than bull trout) (Leary et al. 1991). A bull trout survey in the McKenzie River upstream of Trail Bridge Reservoir identified a likely bull x brook hybrid (Taylor and Reasoner 1998). In streams immediately below high elevation lakes in the Willamette system, naturalized populations of brook trout are also more successful and may limit some rainbow trout distributions (Kostow 1995). However, any influence of brook trout on bull trout is unlikely to be related to Willamette Project activities.

6.1.6.2 Effects Common to All or Most Projects

Willamette Project reservoirs provide extensive habitat for predators of listed species, including native northern pikeminnow (*Pteichocheilus oregonensis*; formerly known as northern squawfish), large lake-residing trout species, smallmouth bass (*Micropterus dolomieui*); largemouth bass (*M. salmoides*), black and white crappie (*Pomoxis nigromaculatus* and *P. annularis*), bull trout, and other native fish including sculpin (*Cottus* sp.) and trout and salmon. Not all of these species are found in all Willamette Project reservoirs, but the total population densities of predators are relatively high in each. Walleye (*Stizostedion vitreum vitreum*) have not been found in any of the reservoirs, but have been captured in the mainstem Willamette River and Middle Fork Willamette River below Dexter Dam. Channel catfish (*Ictalurus punctatus*) are found only in the lower tributaries.

A study was conducted of northern pikeminnow predation on salmonids in free-flowing reaches of the lower Willamette River (Buchanan et al. 1980). Stomach contents of 1,127 northern pikeminnow were analyzed during the spring of 1976 and 1977. Nearly 60 percent of the stomachs contained food items, but only about 2 percent contained salmonids. Principal food types included insects, crayfish, and sculpins, and the majority (94-95 percent) had not consumed more than one principal food type. Reports of high rates of predation on salmonids by northern pikeminnow were thought to reflect special situations such as locations downstream of dams, or following hatchery releases (Buchanan et al. 1980).

It is unknown to what extent drawdown of the reservoirs may limit production of warmwater fish. Each of the reservoirs are drawn-down in the early fall to create storage for winter flood protection. Drawdown exposes the shallow, vegetated shorelines that are used by bass and many other warmwater fish during their first year, and exposes these small fish to higher rates of predation when they are forced to enter the deeper, more open waters. Drawdown can also increase predation rates on juvenile salmonids found in the reservoirs for the same reason (USACE 1996). This would likely affect bull trout and chinook salmon juveniles living in reservoirs. Steelhead juveniles do not appear to enter the reservoirs until the spring outmigration primarily, when the reservoirs have begun filling.

Potential effects of predation on the listed species are greatest for salmonid smolts during their downstream migration, and also for the Oregon chub. The operation of the reservoirs has increased the susceptibility of smolts to predation because of decreased water velocities behind the dams. Studies show that downstream migrating smolts generally move at rates that are a function of the local current velocity (Raymond 1979; Moser et al. 1991). Reduced water velocities increase the travel time of downstream migrating fish, and this can increase the time that smolts are exposed to predation. Disorientation and stresses on smolts probably occur when they pass a dam through the turbines or regulating outlets, or over the spillway, making them more susceptible to predation.

Non-native fish present in the Willamette Project reservoirs have likely contributed to spreading their distribution downstream of each dam. This has likely increased competition and predation rates for juvenile winter steelhead and spring chinook in the respective river reaches downstream of each dam, with adverse effects.

The establishment and expansion of non-native species have contributed to the decline of the Oregon chub and limits the species' ability to expand beyond its current range. However, the current recovery plan (USFWS 1998a) applies to all likely effects of the current operations of the Willamette Project.

Summer streamflow augmentation has resulted in facilitating easier passage at Willamette Falls of non-native fall chinook, summer steelhead, and coho salmon. These species may interbreed or compete directly with listed spring chinook salmon and winter steelhead trout in the upper Willamette River basin.

Production of hatchery species downstream of the dams as mitigation for lost habitat has likely adversely affected listed spring chinook and winter steelhead populations in each river downstream of Willamette Project dams. The hatchery fish likely compete with native species for resources, and may also interbreed.

6.1.6.3 Specific Effects in the Santiam River Subbasin

The effects of dams on predation, species interactions, and community shifts associated with the listed species have not been studied extensively in the Santiam River subbasin. Greatest effects appear to occur in the South and Middle Santiam River subbasins.

6.1.6.3.1 Detroit and Big Cliff Dams and Reservoirs

Detroit Reservoir contains several non-native fish species including warmwater game fish such as brown bullhead (*Ameiurus nebulosus*). Brown bullhead are believed to have originated from illegal introductions prior to dam construction (Wetherbee 1962). With the exception of residualized hatchery chinook salmon in Detroit Reservoir, listed species are generally not found upstream of Big Cliff Dam. It is unlikely that predation, species interactions, and community shifts in the reservoirs affect any of the listed fish species presently.

6.1.6.3.2 Green Peter Dam and Reservoir

The downstream passage facility at Green Peter Dam was "mothballed" in 1988 primarily because of predation problems, where the provision of passage for chinook and steelhead above the dam was discontinued. The reservoir possesses extensive predator habitat for smallmouth and largemouth bass, northern pikeminnows, and numerous other species. Passage efficiency of migrant juvenile salmonids through the lake was approximately eighty percent in the early years after dam construction, but gradually dropped to near zero as predator populations grew in the reservoir and there were not enough fish to sustain runs of either spring chinook or winter steelhead (Buchanan et al. 1993; USACE 1995a). Because no listed species currently migrate upstream of the dam, effects of the Green Peter Dam on predation, species interactions, and community shifts is not likely to adversely affect any of the listed species. However, if listed spring chinook and winter steelhead were reintroduced above the dam (USACE 1993), high predation rates on migrating smolts would be likely to adversely affect those populations.

6.1.6.3.3 Foster Dam and Reservoir

Foster Reservoir contains several non-native fish species including largemouth bass and kokanee. Winter steelhead are passed above Foster Dam and the smolts must pass downstream through the reservoir on their way to the ocean. The reservoir and dam tailrace provide habitat for predators of listed species' juveniles.

The production of hatchery species downstream of Foster Dam as mitigation for inaccessible habitat may have led to the occurrence of residualized summer steelhead smolts in the South Santiam River (Wayne Hunt, ODFW, personal communication, August 1999). These would be expected to compete with native listed spring chinook salmon and winter steelhead in the South Santiam River.

6.1.6.4 Specific Effects in the McKenzie River Subbasin

6.1.6.4.1 Blue River Dam and Reservoir

Blue River Reservoir contains several native fish species that may prey on or compete with planted juvenile chinook salmon residing in the reservoir. It is possible that the reservoir does not contribute significant numbers of predators downstream because of low passage survival and because warmwater fish species are generally not found above the mouth of the Blue River (USACE 1982).

6.1.6.4.2 Cougar Dam and Reservoir

Cougar Reservoir contains several native fish species that could prey on or compete with juvenile chinook salmon and bull trout residing in the reservoir. It is possible that the reservoir does not contribute significant numbers of predators downstream because of low passage survival and because warmwater fish species are generally not found above the mouth of the Blue River (USACE 1982). Water temperatures are generally too cold in Cougar Reservoir for significant exotic species populations to develop (J. Ziller, ODFW, personal communication, August 1999).

6.1.6.5 Specific Effects in the Middle Fork Willamette River Subbasin

6.1.6.5.1 Fall Creek Dam and Reservoir

The effects of Fall Creek Dam on predation, species interactions, and community shifts associated with the listed species are relatively unknown. Fall Creek Reservoir contains several non-native fish species including brown bullhead, largemouth bass, and black crappie. Spring chinook salmon juveniles originating from natural production upstream would likely be adversely affected by predation in the reservoir as they migrate downstream or rear in the reservoir. Predation may also occur in the tailrace on disoriented fish that survive passage through the regulating outlets.

6.1.6.5.2 Hills Creek Dam and Reservoir

Hills Creek Reservoir contains several non-native fish species including brown bullhead, yellow bullhead (*Ictalurus natalis*), largemouth bass, bluegill sunfish (*Lepomis macrochirus*), and black and white crappie. Bull trout are the only listed species found upstream of the dam. Hills Creek Reservoir cannot be completely drawn-down to eliminate exotic species, which are thus likely to have adverse effects on future reintroductions of bull trout.

6.1.6.5.3 Lookout Point and Dexter Dams and Reservoirs

Lookout Point and Dexter reservoirs contain several non-native fish species including brown and yellow bullhead, largemouth and smallmouth bass, bluegill sunfish, and black and white crappie.

Brown bullhead, white crappie and largemouth bass were present by 1985 from illegal introductions, and bluegill sunfish arrived soon after. Kokanee were introduced in 1981 and 1982 only, but are probably extinct there now. Native species also occur in the reservoirs, including northern pikeminnow and largescale sucker (*Catosomus columbianus*) (Seim 1997). Because no listed species currently migrate upstream of Dexter Dam, effects related to predation, species interactions, and community shifts are not likely to adversely affect any of the listed species. However, if listed spring chinook and winter steelhead were reintroduced above the dam (USACE 1997), high predation rates on migrating smolts would be likely to adversely affect those populations. Presently, Dexter and Lookout Point reservoirs may seed the Middle Fork and mainstem Willamette rivers with predators and competitors of juvenile spring chinook salmon and steelhead trout.

6.1.6.6 Specific Effects in the Coast Fork Willamette River Subbasin

6.1.6.6.1 Dorena Dam and Reservoir

Dorena Reservoir contains several non-native fish species including brown and yellow bullhead, bluegill sunfish, largemouth bass, and black crappie (Seim 1997). No listed species are found above the dam. Because of limited historical use by spring chinook above the dam, and current high levels of mercury bioaccumulation in the reservoir (see Section 5.5) it is unlikely that spring chinook would be reintroduced above the dam. However, non-native and native species are flushed downstream into the Row River and the Coast Fork Willamette River annually that could prey on or compete with listed spring chinook or winter steelhead living below the dam.

6.1.6.6.2 Cottage Grove Dam and Reservoir

Cottage Grove Reservoir was chemically treated in 1974 with rotenone to control undesirable fish species, but it subsequently developed a substantial brown bullhead and largemouth bass population (ODFW 1977). Other non-native fish species in Cottage Grove Reservoir include bluegill sunfish, yellow bullhead, and black crappie (Seim 1997). No listed species are found above the dam. Because of limited historical use by spring chinook above the dam, and current high levels of mercury bioaccumulation in the reservoir (see Section 5.5) it is unlikely that spring chinook would be reintroduced above the dam. However, non-native and native species are flushed downstream into the Coast Fork Willamette River annually that could prey on or compete with listed spring chinook or winter steelhead living below the dam.

6.1.6.7 Specific Effects of Fern Ridge Dam in the Long Tom River Subbasin

Fern Ridge Reservoir contains several native and non-native fish species, including abundant populations of warmwater game fish, such as brown bullheads, bluegill, largemouth bass, and black crappie. No listed species are found above the dam and it is unlikely that many occurred historically or currently in the Long Tom River downstream of the dam. However, extreme annual drawdown flushes many of the warmwater fish from the reservoir into the Long Tom River each year, and this could affect predation, species interactions, and community shifts downstream of the dam. It is possible that this results in more non-native fish entering the mainstem Willamette River where they prey on and compete with listed fish species.

6.1.7 Effects of Recreation and Fishing

6.1.7.1 Potential Effects

Impoundments are associated with human recreation activities, including boating, swimming, camping, picnicking, and fishing. Potential impacts from recreational activities include direct mortality to fish by legal and illegal fishing, disturbance to specific lifestages, embryo mortality caused by anglers stepping on salmonid redds, harassment of fish, and changes in habitat quality in terms of water quality and physical habitat characteristics (Marcus et al. 1990). Fishing mortality can occur both in the reservoir and on local rivers and streams. Fishing pressure on the latter may be increased compared to if no dam had been built, because impoundments draw larger numbers of people to a watershed. Catch-and-release regulations reduce but do not eliminate mortality.

Water quality may be influenced through increased bacterial counts and eutrophication due to human and pet waste, petrochemicals from watercraft and vehicles, and contaminated surface runoff from developed areas around the impoundment perimeter. Habitat quality may be influenced by increased use and damage of riparian zones, and increased sedimentation due to motorized vehicle use of lake shores and river beds and damage to riparian zones.

Stocking of reservoirs with catchable fish for recreational purposes may influence naturally-reproducing populations through competition and predation.

6.1.7.2 General Effects Common to All or Most Projects

Willamette Project reservoirs are used to varying degrees for a wide variety of water-dependent and water-related recreational activities including boating, water skiing, fishing, swimming, picnicking, camping, hunting, and others. Many of the recreationers that use the reservoirs also use the rivers and streams upstream of the reservoirs. Operation of the reservoirs also influences recreation use of the river reaches downstream of the dams. Construction of the dams has resulted in the baseline condition of increased angling effort directed at fish stacked-up just downstream.

Responsibility of recreation resource management at the USACE reservoirs is divided among the federal, state, and local entities. The USACE is primarily responsible for resource management at eight lakes, including Fern Ridge, Cottage Grove, Dorena, Dexter, Fall Creek, Foster, Green Peter, and Big Cliff. Recreation site facilities at those lakes are managed by the USACE or are leased to the local entities to operate and maintain for park and recreation purposes. Five of the lakes, including Cougar, Blue River, Lookout Point, Hills Creek, and Detroit are located within the Willamette National Forest. Their recreation resources are managed jointly with the USFS under a Memorandum of Understanding executed by the two agencies in the mid 1950s. Other agencies with various recreation resource management responsibilities include the OSMB, ODFW, Oregon State Parks, and several county and local entities.

Operation of the reservoirs for recreation and recreational activities adversely affects listed species directly and indirectly. In addition to meeting flow augmentation goals, many of the reservoirs are operated to maximize recreational activities by providing full pool elevations during the summer recreation season. For example boaters on the reservoirs typically request that the reservoirs be kept at full pool elevation until after the Labor Day holiday (the first weekend in September). This operating regime can affect fish downstream of the dams by influencing instream flows and temperatures in the mainstem reaches below the dams. Related effects have been addressed in previous sections.

Direct effects of recreation can also occur through fishing, which is an extremely popular activity in the Willamette River basin. For example, surveys conducted in 1972 and 1975 indicated that 2,600,000 trout of all species were caught in 810,000 angler-days in the Willamette River and Sandy River basins combined (USACE 1982). Fishing directly affects listed species through capture and hooking mortality and stress, resulting in "take." The Willamette Project contributes to fishing pressure by providing recreational opportunities in the reservoirs, and the increased numbers of visitors include more anglers, causing increased fishing pressure in the reservoirs, tributaries, and downstream. The dams cause anadromous fish to collect at their base, making them more susceptible to capture either legally or illegally (poaching). The increase in fishing pressure caused by Willamette Project construction has not been estimated, but it is likely to have been greater than if the projects were not constructed, at minimum because of provision of a destination and greater access for recreation. Furthermore, minimum flow releases below the dams have been designed in part to support boating access for angling as opposed to meeting biological needs.

Direct mortality, injury, stress, and/or disease occurs as a result of legal catch-and-release fishing (Clark and Gibbons 1991; Bendock and Alexandersdottir 1993; Bettoli and Osborne 1998). For adult chinook salmon that are caught and released, survival depends on capture method (e.g., catch-and-release, use of bait), fish size, hooking location, and bleeding, and was determined in one study to average 7.6 percent (Bendock and Alexandersdottir 1993).

Fishing affects listed species indirectly by changing the species balance, which influences competition and predation. For example, gear type restrictions limit harvest rates of both native and non-native trout populations that compete or hybridize with one another. Stocking and hatchery releases to support recreational fishing alter the competitive balance between hatchery and naturally produced fish, and support increased fishing effort. Harvest rates suitable for hatchery stocks may be too high for wild stocks if they are not separated from the harvest by either timing restrictions or the use of hatchery marks such as fin clips. Recreational anglers also impact listed species through illegal releases of native and non-native game and bait species (see Section 6.9).

Fishing regulations for all lakes and streams in Oregon are established annually by the ODFW and influence the extent to which recreation-related effects of the Willamette Project are experienced. General regulations for streams and rivers in the Willamette River basin require catch-and-release for trout. For many streams in the Long Tom, Coast Fork, Middle Fork Willamette, and McKenzie river subbasins, however, the limit is 5 trout per day. Catch limits for the lakes generally allow 5 trout per day (other than bull trout) that are at least 8 inches long, and only one trout over 20 inches may be kept per day. Exceptions to these regulations are noted in the following sections. All waters are closed to angling for bull trout and there is no bag limit on the size or number of stream-dwelling brook trout. The current regulations stipulate that only adipose clipped (hatchery reared) salmon and steelhead may be kept. In most waters, the fishing season for chinook salmon is closed during the spring chinook spawning period. Current regulations prohibit the direct taking of any of the listed species, although they may still be taken when they are misidentified. ODFW subbasin plans consider incidental catch of wild and hatchery salmon and steelhead smolts in the trout fishery when setting harvest levels (ODFW 1988a), and ODFW provides illustrations in the sport fishing regulations to help identify species.

Although bull trout may experience incidental mortality and stress by legal fishing activities that are associated with the Willamette Project facilities, those specific effects are currently moot in the context of this BA. This is because the USFWS has determined that applicable state and tribal fishing regulations provide for conservation of bull trout, and has promulgated a special rule that allows for "take" of listed bull trout in the Willamette River basin when it is in accordance with ODFW fishing regulations, pursuant to Section 4(d) of the ESA (63 FR 31673). However, the special rule also states that in the event that any of the regulations are modified in a manner that is inconsistent with conservation of bull trout, the 4(d) rule would not allow the "take" of bull trout. The NMFS is proposing similar special rules regarding "take" in accordance with state fishing regulations for the other listed salmonid species found in the Willamette River, subject to the condition that the regulations meet specific criteria that are protective of each ESU (64 FR 73479; 65 FR 170).

Day use and overnight camping has negative impacts on listed species when these activities influence the condition of the riparian areas (Clark and Gibbons 1991). Recreational use along shorelines can result in modifications to the lakebed and streambank structure due to foot traffic, which reduce instream cover and increase sedimentation. Camping also often results in the removal of vegetation along the banks where areas are cleared for tent sites or for firewood. Day use and overnight camping impacts water quality when it results in increased inputs of trash and human waste into the water. Designated and maintained campsites help reduce these impacts by containing these negative impacts to smaller areas.

Recreational boating may negatively influence listed species in several ways. The use of motor boats on reservoirs and rivers negatively impacts fish and fish habitat when gasoline and oil is released into the water. The wake from motorized boating increases the rate of erosion along the shoreline. Direct mortality can occur when listed fish come in contact with boat propellers or jet intakes. Boaters may also affect listed species when pool levels and river flows are maintained for boating activities instead of for fish and fish habitat. The use of drift boats for fishing on the rivers also potentially disturbs spawning and incubating fish when anchors are dragged along the streambed.

Incidental mortality of listed salmonids may occur as a result of anglers walking over spawning beds. Results of a study showed that angler wading resulted in measurable mortality on brown trout, cutthroat trout, and rainbow trout eggs and pre-emergent fry buried 15 cm deep, ranging between 11 and 96 percent mortality when walked on twice, and 0 and 43 percent when walked on once (Roberts and White 1992). Such mortality is likely to be lower for chinook salmon and steelhead, however, because they bury their eggs deeper (DeVries 1997).

Swimming, which typically has a benign impact on the environment, negatively impacts anadromous salmonids when swimmers disturb adult salmonids that are holding in deep river pools during the warm months of their spawning migration. This type of disturbance has been documented in Quartzville Creek upstream of the Green Peter Dam and in Fall and Winberry creeks upstream of Fall Creek Dam (Skeesick and Jones 1988). The relationship between operation of the USACE dams and swimming activities in the rivers upstream cannot be quantified; swimming in rivers downstream of the dams likely has a more direct relationship to project operations due to increased summer flows.

Recreation also has several potential positive impacts on the species of concern. Many anglers and hunters are active conservationists who support organizations and legislation aimed at protecting the resources they enjoy. Some recreation users, such as boaters and hikers, are also influential advocates of species and ecosystem conservation. Additionally, recreation use potentially increases public awareness of the values of, and the need to, protect the species of concern, and these factors potentially help guide management and research designed to benefit the listed species.

6.1.7.3 Specific Effects in the Santiam River Subbasin

6.1.7.3.1 Detroit and Big Cliff Dams and Reservoirs

Detroit Dam and Reservoir are located within the Willamette National Forest. Big Cliff Dam and Reservoir are located outside of the national forest boundary. Limited recreational activity occurs in Big Cliff Reservoir because of access and safety concerns related to the operation of the Big Cliff project as a re-regulating facility for Detroit Dam. Detroit Reservoir is a popular recreation area for water skiing, swimming, fishing, and boating. The Oregon State Parks Department operates two parks that include picnicking, swimming, camping and boat launch facilities. The USFS operates three campgrounds on the reservoir. There is boat access at both full and low pool (Skeesick and Jones 1988).

Detroit Reservoir is stocked with fingerling and legal sized rainbow trout and fingerling kokanee. A residualized, land-locked chinook salmon population is also found in the reservoir and juveniles are currently released into the reservoir to help maintain this population. Chinook salmon that are less than 15-inches long are considered “trout” and are subject to the 5 per day bag limit. Other species available for recreational fishing include cutthroat and brook trout, brown bullhead, and other non-native warmwater fish species. Fishing pressure has been extensive; for example, 134,000 anglers caught 228,000 trout in Detroit Reservoir in 1960 (USACE 1982).

ODFW collects hatchery-reared summer steelhead at the Minto Dam and then transports them back down the river so that anglers have additional chances to capture them (this practice is termed "recycling"). The angling season for steelhead in the North Santiam and mainstem Santiam rivers and in the Little North Santiam River is open the entire year. Trout fishing below Big Cliff Dam is regulated for catch-and-release. Upstream of Detroit Reservoir, trout anglers can keep 5 trout per day and baited hooks may be used.

Because fish species listed under the ESA are not found in the waters upstream of Detroit Dam, recreational fishing above the dam is not likely to adversely affect any of the listed species.

Fishing downstream of Big Cliff Dam (or more likely downstream of the Minto Dam) is likely to result in catch-and-release of listed winter steelhead and spring chinook adults and smolts, in which incidental mortality may occur from related injuries. In 1972, anglers in the North Santiam River fished a total of 217 hours, and caught 160 rainbow trout, and 17 steelhead (Campbell and Daily 1972). Of these, 14 steelhead smolts and 70 rainbow trout were between 6 to 8 inches long, and some of the rainbow trout may have been steelhead pre-smolts. Trout and steelhead fishing in the North Santiam River is also likely to result in unknown levels of mortality to listed winter steelhead, as is poaching. Big Cliff and Detroit dams may therefore adversely affect listed winter steelhead and spring chinook salmon individuals by increasing their susceptibility to fishing pressure below them.

6.1.7.3.2 Green Peter and Foster Dams and Reservoirs

Green Peter and Foster reservoirs provide opportunities for fishing, boating, water skiing, camping, and picnicking. The Linn County Parks and Recreation Commission operates two boat ramps on Green Peter Reservoir and three boat ramps on Foster Reservoir. The USACE operates two boat ramps on Foster Reservoir. Facilities for camping and picnicking are also available at both lakes.

Power generation at Green Peter Dam results in large water level fluctuations in the short stretch of the Middle Santiam River above Foster Reservoir. The daily water level fluctuations and velocity changes preclude the use of this reach for sport fishing. Recreational salmon and steelhead fishing is a popular activity below Foster Dam. Because species listed under the ESA are not found currently in the Middle Santiam River upstream of Green Peter Dam, fishing in this area is currently not likely to adversely affect any of the listed species. This assessment could change if listed species are reintroduced.

Prior to the ESA listing of Upper Willamette steelhead as threatened, ODFW estimated that restoring steelhead production above Foster Dam to pre-dam production levels would increase angling opportunities on 40 miles of habitat with good public access, good water flow, and low turbidity. Angling opportunities would also be increased between Lebanon and Foster dams (Buchanan et al. 1993).

Fishing downstream of Foster Dam is likely to result in catch-and-release of listed winter steelhead and spring chinook adults and smolts, with associated incidental mortality and stress. Currently, ODFW regulations allow angling for steelhead downstream of Foster Dam throughout the entire year. Summer steelhead collected at the fish trap just below Foster Dam are transported back downstream so that anglers have additional chances to capture them. Trout fishing below the dam and in the South Santiam River upstream of Foster Reservoir is regulated for catch-and-release. Upstream of Green Peter Reservoir, 5 trout per day may be kept and the use of baited hooks is permitted. Additionally, up to 25 kokanee may be kept each day from Green Peter Reservoir.

In 1982, the USACE monitored fishing pressure on wild and hatchery steelhead smolts during a smolt passage study at Foster Dam (USACE 1993). Between 16 April and 5 June, about 6,800 anglers in Foster Reservoir fished 17,100 hours and caught 1,133 hatchery and 275 wild smolts (Table 6-15). The catch of hatchery smolts was estimated to represent between 3 percent and 4 percent of the smolts released above Foster Dam. Buchanan et al. (1993) considered this to not be an important source of mortality in Foster Reservoir. However, given the current listing status of winter steelhead, capture of listed smolts corresponds to "take" under the ESA.

Table 6-15 Angling and steelhead smolt catch in Foster Reservoir, Oregon, from 16 April to 5 June 1983 (from USACE 1993).

Item	During Spill[a]	Post Spill[b]	Total
Anglers	4,005 ±791	2,806 ±413	6,811 ±893
Angler hours	9,796 ±1,562	7,305 ±846	17,101 ±1,1776
Hatchery smolts caught	482 ±271	651 ±201	1,133 ±363
Wild smolts	125 ±68	150 ±68	275 ±95

a = The Foster Dam freefall spill operated from 16 April to 15 May.
b = Catch was monitored from 16 May to 5 June.

Off-road vehicle activity along the shoreline of Foster Reservoir has recently increased in popularity. A permitted off-road event, the "Mud Races," is held at Foster Reservoir each year and attracts thousands of people. Off-road vehicle use has the potential to adversely affect all fish in and downstream of the reservoir through increased turbidity caused by erosion. The permitted use of off-road vehicles within the drawdown zone of Foster Reservoir is also likely to result in spills of toxic materials within the ordinary high water mark of reaches that contain listed winter steelhead. There is insufficient information available regarding the magnitude of the potential spills, and the dilution and bioavailability of the released substances to quantify the effects of this impact. It is unknown whether this recreational activity is likely to adversely affect listed fish species in Foster Reservoir. Dilution may be sufficient to preclude adverse effects downstream of Foster Dam in the near term, although the possibility exists for longer term adverse effects through bioaccumulation of persistent toxins. Recent studies by Arkoosh et al. (1994) suggest that related organic contaminants may negatively affect the immune systems of juvenile salmon, and their overall survival.

6.1.7.4 Specific Effects in the McKenzie River Subbasin

6.1.7.4.1 Blue River Dam and Reservoir

Blue River Reservoir is located within the Willamette National Forest and there are two day-use and camping facilities at the lake that are managed by the USFS. Fishing, swimming, and water skiing are available at the two recreation areas, both near the upper end of the lake. The reservoir is drafted first among the 13 Willamette projects, and consequently in some years it experiences a substantial drawdown during mid-summer that limits recreation. Under current operations, boaters are unable to launch by mid-July via the Lookout boat ramp (USACE 1995a). Reservoir margins have been planted by the USFS to enhance drawdown margins with bald cypress (*Taxodium distichum*), Pacific willow (*Salix laciandra*), coyote willow (*Salix exigua*) and Columbia sedge (*Carex aperta*). This provides a more scenic view during low pools and provides erosion control and fish and wildlife cover (Skeesick and Jones 1988).

Blue River below the dam, and the McKenzie and South Fork McKenzie rivers have experienced a recent increase in rafting and boating (USACE 1995a). It is unknown whether this is likely to adversely affect listed species.

The reservoir is stocked with catchable rainbow trout in the spring (Skeesick and Jones 1988). Legal-size rainbow trout are also stocked upstream of the reservoir. Fishing regulations upstream of the dam allow 5 trout per day. Downstream of the dam, only hatchery-reared trout that are marked with a clipped adipose fin may be kept. Fishing for steelhead and salmon is currently not allowed in the Blue River.

Because species listed under the ESA are not found in the waters upstream of Blue River Dam, recreational fishing above the dam is not likely to adversely affect any of the listed species.

Fishing downstream of Blue River Dam may result in catch-and-release of listed bull trout and spring chinook adults and smolts, and therefore incidental mortality or stress. The high fishing pressure in the river for trout may also result in unknown levels of mortality as a result of poaching. Recreational fishing downstream of the dam is likely to adversely affect listed any bull trout and spring chinook individuals that might attempt to migrate upstream or hold below the dam. However, incidental take of bull trout is currently permitted under ESA (63 FR 31673) as described earlier, and summer and fall water temperatures may preclude their presence (Section 6.1.2).

6.1.7.4.2 Cougar Dam and Reservoir

Cougar Dam and Reservoir are located within the Willamette National Forest and all of the project's recreation facilities are managed by the USFS. Three boat ramps are useable at water surface elevations above 1,635 feet. Visitors are attracted primarily to fishing, and although the trout fishery is not dependent on high lake levels, users want boat ramps to stay usable through Labor Day. Early drawdown exposes large areas for off-road vehicle use and impact, and the USFS has undertaken a long-term effort to revegetate the drawdown zones in the lake (USACE 1995a).

Fishing for salmon is currently not allowed in the McKenzie River and its tributaries. Fishing for steelhead is restricted to only adipose fin-clipped steelhead from the mainstem McKenzie River, Walterville canal, and South Fork McKenzie River. The McKenzie River is popular for trout fishing. Currently, only the mainstems of the McKenzie and Blue rivers are stocked with hatchery rainbow trout. In the upper waters where hatchery trout are not released, the trout fishery is regulated for catch-and-release of all trout except brook trout, for which there is no bag limit. Current regulations require that wild trout captured in the mainstem McKenzie River be released.

In 1983, ODFW conducted a creel survey on the McKenzie River throughout the trout season (23 April-31 October) (Hutchison and Hooton 1990). Angler effort and catch projections were made from Armitage Park to the town of Blue River, excluding Leaburg pool, a distance of 51 miles. Approximately 38,400 bank anglers and 15,300 boat anglers fished in the 51-mile survey section. These anglers kept about 53,700 fish. An additional 36,200 non-angler recreational boaters floated this surveyed reach during the trout season. The estimated total catch comprised 38,153 (71%) hatchery rainbow trout, 4,912 (9%) wild rainbow trout ("redsides"), and 10,671 other fish including mostly hatchery steelhead smolts (Table 6-16). These numbers do not reflect that 1983 regulations required that rainbow trout 14 inches or longer be released. Although anglers did keep some of these fish, it was estimated that one large rainbow trout was released per 517 anglers.

Table 6-16. Estimated angler effort and catch in the McKenzie River, Oregon, 1983 trout season (from Hutchison and Hooton 1990).

Category	Total Number
Anglers	53,712
Fish caught	53,736
Angler hours	164,278
Fish per hour	0.33
Catch by species	
Hatchery rainbow trout	38,572
Wild rainbow trout	2,907
Bull trout	5
Mountain whitefish	246
Hatchery steelhead smolts	7,629
Wild summer steelhead smolts	111
Hatchery spring chinook smolts	1,900
Wild spring chinook smolts	39
Adult spring chinook	174
Adult summer steelhead	153

Overharvest prior to the enactment of protective fishing regulations is one of the factors believed to have contributed to the decline of bull trout populations in the McKenzie River subbasin (USACE 1995a). Bull trout are aggressive feeders and readily take lures or bait, making them very susceptible to fishing pressures (ODFW 1997b). Bag limits were 5 trout per day until 1996, when take of bull trout in the Willamette River basin was prohibited. Additionally, until about this same time, the South Fork McKenzie River above Cougar Dam was stocked annually with legal-sized rainbow trout, which maintained a high fishing effort in the system. This stocking program has been halted to limit the incidental catch of bull trout (J. Ziller, ODFW Springfield, personal communication, November 1999). Continued catch-and-release fishing for rainbow trout and steelhead, and legal catch of brook trout is likely to adversely affect bull trout as a result of incidental catch, poaching, and unintentional mortality or stress. However, incidental take is currently permitted under the ESA (63 FR 31673) as described earlier.

Fishing downstream and upstream of Cougar Dam is likely to result in catch-and-release of listed bull trout and spring chinook adults and juveniles, and therefore incidental mortality or stress of these listed species. Permitted catch of brook trout is also likely to result in unknown levels of mortality to bull trout as a result of misidentification of retained fish, since the two species have similar coloration. Because mortality is a likely result of recreational fishing above and below the dam, recreational fishing is likely to adversely affect listed spring chinook and bull trout individuals.

In low flow years, there may be increased chances for entrainment of bull trout in the regulating outlets because the water surface elevation is closer to the intake elevation. It is unknown whether bull trout are affected adversely by this feature of reservoir level management.

6.1.7.5 Specific Effects in the Middle Fork Willamette River Subbasin

6.1.7.5.1 Fall Creek Dam and Reservoir

Fall Creek Reservoir is only 20 miles southeast of Eugene and attracts substantial numbers of recreationers. The Lane County Parks Department manages two day-use recreation facilities for boating, water skiing, fishing, swimming, and picnicking on the reservoir, and the USACE manages two campgrounds. SKY Camp, an outdoor youth education and recreation facility dedicated in 1978, was developed in cooperation with the Bethel School District and the Springfield Kiwanis Club.

Fall Creek Reservoir is stocked regularly with trout because the annual fall drawdown removes the majority of the trout population (Skeesick and Jones 1988). Adult winter steelhead have been transported above Fall Creek Dam so they can access 50.8 miles of spawning habitat in Fall and Winberry creeks (Skeesick and Jones 1988), although historically the subbasin did not support winter steelhead. Harassment and snagging of spring chinook holding in deep river pools was of a sufficient magnitude that it was cited as a reason that ODFW stopped transporting spring chinook above the dam (Skeesick and Jones 1988). However, adult spring chinook have been released above the dam again in recent years.

Two salmon or adipose-fin-clipped steelhead can be kept from Fall Creek up to Fall Creek Dam, and from the Little Fall Creek from its mouth up to the fish ladder 12 miles upstream. These streams also have special catch-and-release requirements for rainbow and cutthroat trout from November through April.

Because adult winter steelhead and spring chinook salmon are transported above Fall Creek Reservoir, recreational fishing above the dam is likely to result in catch-and-release of adults and smolts, with attendant mortality or stress. Recreational fishing downstream and upstream of the dam is therefore likely to adversely affect listed spring chinook individuals.

6.1.7.5.2 Hills Creek Dam and Reservoir

Hills Creek Reservoir is surrounded by the Willamette National Forest. Although this reservoir is one of the higher elevation lakes within the Willamette Project and is fed by relatively cool streams, it is more popular for warmwater fishing. Trout production within the reservoir is assumed to be limited by the effects of high turbidity and drawdown (Skeesick and Jones 1988). Turbidity results from erosion of fine clay along the shorelines during summertime wave action; 200 acres of shoreline were revegetated several years ago (Skeesick and Jones 1988). Recreation facilities at Hills Creek Reservoir are managed by the USFS and include day-use and overnight campgrounds.

Hatchery rainbow trout are stocked upstream of Hills Creek Reservoir, and only adipose fin-clipped trout can be kept except for brook trout, for which there is no bag limit. Angling is no longer allowed for bull trout, but fishing for hatchery rainbow trout can adversely affect bull trout through incidental catch, poaching, and mortality or stress from catch-and-release.

Bull trout are the only listed fish species potentially present upstream of the Hills Creek Dam, although there is considerable doubt that any fish remain currently (Buchanan et al. 1997). Trout fishing upstream of the dam would be likely to result in catch-and-release of bull trout should they be reintroduced, with attendant mortality and stress. However, incidental take of bull trout is currently permitted under ESA (63 FR 31673) as described earlier.

6.1.7.5.3 Lookout Point and Dexter Dams and Reservoirs

Peak recreational use occurs during the summer months, but warm weather early in the spring or late in the fall can extend the period of use. Lookout Point and Dexter reservoirs and surrounding lands are used for camping, picnicking, boating, fishing, and swimming. While fishing is not dependent on high pool elevations, anglers desire that the boat ramps remain useable through Labor Day. Dexter Reservoir is popular for boating activities and is known for its low level of wave buildup, making it attractive to high-speed boaters. Recreational use on Lookout Point Reservoir is constrained by the lack of facilities and difficult access. Off-road vehicle use has gained in popularity at this reservoir although this use is not permitted. The USACE is attempting to remove access to the lake bed by off-road vehicles at the Armet Creek access area to the Lookout Point Reservoir.

Lookout Point Reservoir supports a relatively limited sport fishery in comparison to the other Willamette Project reservoirs. The reservoir provided good trout fishing for only the first three years following its construction in 1954 (Seim 1997). It is also not used heavily for warm water fisheries. In 1986, the estimated angler use was less than 2,000 fisher days/years. The relative lack of shallow, low gradient shoreline areas colonized by grasses, sedges, and other aquatic plants likely contributes to lowered productivity of warmwater game fish species. Spring chinook have been stocked annually since 1983 and form a major part of the sport fish catch in the reservoir (Seim 1997).

Fishing is allowed for salmon and adipose fin-clipped steelhead in the mainstem river below Dexter Dam; the area below the dam is an extremely popular location for spring chinook angling in particular. In 1989, fishing in the Middle Fork Willamette River accounted for an estimated 40 percent of the annual visits to Dexter Reservoir (USACE 1997). Anglers have requested that increased flows be released during the spring chinook run to enhance fishability of the river. Drift fishing is popular in the lower river (Skeesick and Jones 1988), but fishing from a boat or other floating device is not allowed immediately downstream of the dam or near the fish collection facility. To best accommodate boat anglers, ODFW has recommended that flows of 1,500 to 2,500 cfs be maintained below Dexter Dam from May to August (USACE 1997). Assuming that catch is increased as a result of increased efficiency for boat anglers, the practice may adversely affect listed spring chinook salmon in the mainstem river through take.

There is an important wild trout fishery in the Middle Fork Willamette River between Hills Creek Dam and Lookout Point Reservoir. ODFW has recommended that releases of 400-500 cfs at Hills Creek Dam be maintained during summer to support this wild trout fishery (USACE 1997). All trout fishing in the Middle Fork Willamette River from the mouth up to Hills Creek Dam is regulated for catch-and-release. The North Fork of the Middle Fork Willamette River (above Westfir) has been managed as wild trout stream since 1980 (Skeesick and Jones 1988). The McKenzie Fly Fishers, a Eugene-based organization is involved in monitoring activities that could affect trout populations (Skeesick and Jones 1988). Trout fishing in the North Fork of the Middle Fork Willamette River is restricted to fly fishing. Limited rainbow trout can be kept during the summer, but they must be released during the period from November through April.

Because game species listed under the ESA are currently not found in the waters upstream of Dexter and Lookout Point dams, recreational fishing above the dams is not likely to adversely affect any of the listed species.

6.1.7.6 Specific Effects in the Coast Fork Willamette River Subbasin

6.1.7.6.1 Dorena Dam and Reservoir

Recreation areas have been developed by the USACE and Lane County at Dorena Reservoir, where water skiing, boating, and swimming are popular activities. Lane County manages several day and over-night use sites and boat ramps. The USACE manages minimally-developed campground with river access just downstream of the dam. There is a state health advisory on eating fish from Dorena Reservoir due to mercury contamination. Nonetheless, the lake is popular for its warmwater fishery.

Fishing for salmon and adipose fin-clipped steelhead is permitted in the Row River downstream of the Dorena Dam, although the river contains relatively few fish. This section of river is also open for trout fishing, although from November through April they must be caught-and-released. The other tributary streams are open for trout fishing except from November through April. Because game species listed under the ESA are generally not found in the waters upstream of Dorena Dam, recreational fishing in the reservoir is not likely to adversely affect any of the listed species.

6.1.7.6.2 Cottage Grove Dam and Reservoir

Cottage Grove Reservoir is used for boating, swimming, picnicking, camping, fishing and hunting. Two overnight campgrounds and three day-use parks are located along the shoreline. There is a state health advisory on eating fish from Cottage Grove Reservoir and the river downstream of the dam due to mercury contamination. Nonetheless, the lake and the downstream river are popular for its warmwater fishery. Water quality impairment of the river downstream of the dam due to high levels of fecal coliform bacteria limits the use of this reach for swimming.

Fishing for salmon and adipose fin-clipped steelhead is permitted in the Coast Fork Willamette River downstream of Cottage Grove Dam, although like the Row River, there are relatively few fish. This section of river is also open for trout fishing, including catch-and-release from November through April. The other tributary streams are open for trout fishing except during the period from November through April. Because game species listed under the ESA are not found in the waters upstream of Cottage Grove Dam, recreational fishing in the reservoir is not likely to adversely affect any of the listed species.

6.1.7.7 Specific Effects Related to Fern Ridge Dam and Reservoir in the Long Tom River Subbasin

Fern Ridge Reservoir supports a strong demand for recreation. The reservoir is filled to the maximum pool elevation in the spring and is maintained at maximum level as long as possible through the summer. Because of its high priority for recreation, the lake is not drafted for meeting flow requirements on the mainstem Willamette River during the summer (OWRD 1999). This is probably beneficial because of the high water temperatures that develop during the summer. In 1971, the multi-agency Willamette Basin Comprehensive Study included recommendations for modification of the project to permit fuller use of recreational potential without hindering irrigation and flood control uses. Fern Ridge Reservoir is used heavily for picnicking, swimming, sailing, water skiing, and fishing. The USACE operates two parks on the reservoir, and Lane County Parks Department manages three facilities.

Fern Ridge Reservoir is probably the most popular reservoir for warmwater fishing, especially for crappie, bass, and brown bullhead (Daily 1999). Production of warm-water fish in the reservoir is limited, however, by low winter drawdown elevations. The extreme drawdown flushes many of the warmwater fish from the reservoir into the Long Tom River each year. This supports an active fishery in the Long Tom River downstream of the dam, although access to this river is difficult (Daily 1999). Although naturally too warm to support a large trout population, the Long Tom River is open for trout fishing year-round, with catch-and-release only during the period from November 1st to April 23rd. Some of the warmwater fish flushed out of the reservoir may make it to the mainstem Willamette where they may prey on juvenile salmonids and Oregon chub. Drawdown may therefore adversely affect listed species in the mainstem Willamette River.

None of the listed fish species are present in the Long Tom River subbasin, and the Long Tom River most likely did not historically support steelhead or chinook as a result of naturally poor summer rearing conditions (ODFW 1990d). Because this subbasin did not historically or currently support the listed fish species, recreational fishing associated with Fern Ridge is not likely to have adverse affects on listed species.

6.1.8 Other Habitat-Related Effects of the Willamette Project and Bank Protection Program

The Willamette Project and bank protection works influence the fine sediment budget in the Willamette River and tributaries. Fine sediment deposition in streams can impair salmonid spawning, rearing, and overwintering habitat in particular. Specifically, high sediment levels in salmonid spawning and rearing habitat can reduce delivery of oxygen and removal of metabolic waste products, or trap developing and emergent embryos residing within the gravel. Salmonid egg-to-fry survival is correlated negatively with concentrations of fine sediment deposited in a stream. Egg-to-fry survival begins to decline when fine sediment (< 6.4 mm) levels increase above approximately 20 percent. Survival to emergence declines rapidly when sediment levels reach around 30 percent and greater. Pools and interstitial substrate spaces may fill with fine sediments, resulting in reduced feeding, rearing, and overwintering habitat. High levels of fine sediments can also limit or change the structure of aquatic macroinvertebrate communities that serve as a food source (Bjornn et al. 1977; Chapman and McLeod 1987).

Because of existing bank protection works and reduced fine sediment loading downstream of the dams, the present volume of fine sediment potentially contributed by the Willamette Project is small relative to the total current and historic sediment loads of the river. Conversely, reduced flood magnitudes and frequencies have likely reduced the degree of flushing of fine sediments from substrates in lower gradient reaches downstream of dams, which has likely led to increased fine sediment levels within the substrate (Petts 1984; Marcus et al. 1990). Salmonid spawning activity generally does not occur in the mainstem Willamette River, but spawning does occur further upriver in tributaries, below Willamette Project facilities. Overwintering habitat within the Willamette River could also be influenced by sediments depending on the availability and abundance of large substrates and pool habitat relative to population densities observed presently and expected in the future. Whether these effects have adversely affected listed fish species is unknown presently.

Other activities associated with flood and flood damage control have resulted indirectly in changes to habitat conditions at small and large scales. It is difficult to separate out those indirect effects attributable to the Willamette Project from other cumulative effects per definitions under the ESA (see Chapter 7). Such cumulative effects are related indirectly to the Willamette Project because it has facilitated development throughout the Willamette Valley.

At the largest scale, flood control has led to increased agricultural and urban development throughout the entire Willamette Valley. Urban development has included creation and expansion of industrial, commercial, and residential areas. The myriad impacts of each have been extensive in scope and magnitude, and have included habitat loss, physical habitat modification, reduced water quality, eutrophication, increased (legal and illegal) fishing pressure, and numerous other direct and indirect impacts.

At smaller scales, development of the Willamette Valley as a consequence of flood control has also led to channelization and extensive loss of side channel habitat (i.e., roughly 50 percent from historic; Benner and Sedell 1997), as described in Section 6.1.5. Bank protection works have reduced habitat complexity and quantity depending on the design and fish species. Bank protection and channelization has reduced or eliminated input of woody debris and nutrients from the riparian zone. Flood control and bank protection has also modified habitat quantity and quality through channelization and elimination of side channel and slough habitat, which is important for withstanding adverse effects of flood control operations. For example, Li et al. (1984) noted that many of their study sites in the mainstem Willamette River were "flushed out" by a sudden release of water from Lookout Point Dam. All of these effects can be considered to be adverse to varying degrees.

Li et al. (1984) evaluated the relationship between habitat character of various bank protection works and densities of young of year and adult fishes in the mainstem Willamette River, as a followup to previous work (Hjort et al. 1983, cited in Li et al. 1984) in which it was determined that higher densities of a smaller number of fish species were found associated with revetment habitats than with natural streambank habitats. The greater diversity of habitat found in the vicinity of natural banks was associated with a greater number of fish species. Aquatic macroinvertebrate species composition and diversity also differed between the two types of habitat because of differences in hydraulics and in the stability and morphology of the bank surface. Li et al. (1984) determined that continuous revetments provided relatively little usable habitat for young fish in the Willamette River because of the proximity of fast and deep water making them more susceptible to predation, and the occurrence of lower water temperatures than in shallower water habitats. Spur dikes provided greater habitat diversity than continuous revetment, and caused the settling out of woody debris and fine sediments in between dikes that provided shallower, slower water suitable for larval fish. Natural habitats were considered to include secondary channels, fast and slack water banks, sloughs, and backwaters. These habitats provided greater physical diversity that was used more extensively by juvenile chinook salmon than the habitats associated with bank protection works, although some use of spur dike habitat was also recorded.

Two recent studies have evaluated the relationship between bank protection works and fish habitat and abundance. Beamer and Henderson (1998) studied juvenile salmonid habitat use in the mainstem Skagit River, Washington. Juvenile chinook salmon abundance was correlated with the amount of wood cover along the bank, and was higher when cover was provided by root wads than by single logs. Juvenile rainbow/steelhead trout were determined to be less sensitive to bank type and were inclined to use rip-rap banks when the rock particles were large. Peters et al. (1998) determined that rip-rapped banks had consistently lower densities of fish (including predominantly salmonids) than natural banks within each stream surveyed. Banks stabilized with large woody debris were noted to have more fish than natural banks. There were some seasonal differences noted in fish use of banks stabilized using flow deflectors, which appeared to be more favorable during the winter.

These results suggest collectively that reaches with cover provided by natural bank structure contain greater densities of salmonids and other fish species than riprapped banks. Juvenile anadromous salmonids use the mainstem Willamette River and lower reaches of the major tributaries to rear and rest as they migrate downstream to the Pacific Ocean. Both winter steelhead and spring chinook have also been noted to spawn infrequently in the mainstem upstream of the Long Tom River, and their offspring appear to live year-round in the system (USACE 1975). Juveniles of other listed species found below Willamette Falls use that reach of the river in similar contexts. The extensive modification of streambanks in the mainstem and lower reaches of subbasin tributaries because of bank protection works has resulted in reduced habitat availability and carrying capacity for juvenile salmonids, and likely increases the opportunity for predation. The extent to which present populations could be limited in this way is unclear, however, because populations are low due to a large variety of causes including many described elsewhere in this BA. This influences the number of juveniles that would be available for rearing and resting in the mainstem. Densities of a particular lifestage and species associated with different bank cover types vary within and between river systems because of local population size, environmental factors, and behavioral differences, and it is therefore difficult to apply a density from one stream to another as a reference or target value. More specific information would need to be collected in the Willamette River basin to identify characteristic fish densities, and experimental control would be needed to determine the site specific effects of bank protection on carrying capacity within the system. The effect of bank protection works on listed salmonid species consequently may not be differentiable quantitatively from other effects at the present time.

Despite these uncertainties, it is nonetheless evident that the bank protection program has adversely modified habitat quality and quantity for listed fish species, and may make juvenile salmonids more vulnerable to predation because of the reduced availability of cover and refuge habitat. Bank protection works has also likely adversely affected habitat quality and quantity indirectly by influencing geomorphic channel and floodplain maintenance processes.

Oregon chub habitat has also been reduced in quantity and quality because of bank protection works. The associated elimination and alteration of protected slackwater habitats required by chub has made them more vulnerable to predation, in particular (USFWS 1998a). This has likely affected Oregon chub distributions adversely in the protected reaches and probably contributed to their decline.

6.1.9 Effects of Hatcheries

Hatchery operations have likely had a number of direct and indirect effects on listed fish species in the Willamette River basin. This section summarizes those effects, which will be the subject of a separate consultation.

Potentially beneficial influences include supplementation of populations that are at critically low levels, where the increased survival from egg to fry or juvenile in artificial propagation compared to naturally-reproduced fish may help maintain populations until they are able to rebound naturally. Depending on the size of stream, hatchery facilities may effect nutrient loading downstream, influencing productivity.

However, several adverse effects have also likely occurred. Genetic introgression has probably occurred through inter-basin stock transfers at Willamette Project hatchery facilities and subsequent inter-breeding between wild and strayed hatchery fish. Such transfers have been sufficiently extensive in the past that fish derived from natural spawning likely have genes originating from non-native stocks. It is difficult to determine except under very clear physical, environmental, and/or historical conditions whether present populations should be classified as consisting of wild (i.e., no hatchery genes) or naturally-produced (i.e., stock has experienced interactions with hatchery) fish. Hatchery stocks may have also experienced inbreeding, although modern practices now discourage such an effect. Overall, however, the fitness of the resulting offspring for spawning and surviving successfully in the wild may be in question as a result of genetic effects.

Other, adverse effects have likely included increased juvenile competition between artificially- and naturally-produced fish for food and rearing habitat. Hatchery fish have typically been larger on release than comparably-aged, naturally-produced fish and thus may have been able to outcompete whenever size conferred an advantage. Furthermore, larger hatchery juveniles have been able to prey on smaller natural fish. Hatcheries have also been subject to diseases because of the increased density of fish in rearing facilities, and these fish may have been carriers of diseases that have affected naturally-produced fish subsequent to release. Increased hatchery production has also encouraged increased fishing effort, and hatchery stocks have been able to sustain higher fishing pressures than naturally produced stocks, potentially resulting in over-fishing.

Adults that enter trapping facilities below Willamette Project dams may incur injury or disease prior to being taken to hatcheries for egg-taking and fertilization, or transport upstream. It is unknown whether this effect is sufficiently adverse to result in reduced spawning fitness, or if any trapped fish that might die has a significant influence on overall reproductive potential of the ESU. Improvements to these trapping and handling facilities are currently under study.

6.1.10 Effects of the Willamette Project Downstream of Willamette Falls

The Willamette Project is unlikely to adversely affect listed species in terms of direct effects. With the exception of the dilution benefit obtained by increased summer flows, adverse flow, water quality, and geomorphic effects of the Willamette Project are unlikely to be significant below the falls because the Willamette River is under the hydraulic and tidal influence of the larger Columbia River, water temperatures have equilibrated with ambient conditions by the time water from the dams reaches the falls, and several tributaries join with the mainstem Willamette River below the Santiam River. Each tributary contributes to the mainstem, in addition to flow and sediment, its own potentially adverse water quality characteristics related to urban and agricultural development. In other words, the Willamette Project facilities are too far removed in space from listed fish populations below Willamette Falls to have a specific, significant adverse effect that can be linked to specific project operations.

The Willamette Project has indirectly affected listed species adversely below Willamette Falls through the cumulative effects of non-federal activities associated with population growth and development. These activities have been facilitated by flood control, water storage, bank protection, hydroelectric production, navigation, and recreation afforded by the Willamette Project. To the extent that these effects result in degraded habitat and take, the Willamette

Project has had an adverse, indirect effect on listed species that occur there. Cumulative effects are summarized in Chapter 7.

6.2 WILDLIFE

6.2.1 Gray Wolf

While there may be suitable habitat for this species in proximity to the Willamette Basin Projects, the operation and maintenance of the projects would have no effect on the gray wolf.

6.2.2 Columbian White-tailed Deer

While suitable habitat exists, it is not likely to be occupied unless the range of the current Douglas County population expands to the north. Consequently, the operation and maintenance of the USACE Willamette Valley Projects are not likely to adversely affect the Columbian white-tailed deer.

6.2.3 Marbled Murrelet

Based on the location of the projects and the lack of suitable habitat, the operation and maintenance of the Willamette Basin Project would have no effect on marbled murrelet.

6.2.4 Aleutian Canada Goose

Based on the limited potential for the Aleutian Canada goose to occur at the Fern Ridge project, and the current lack of hunting opportunities on project lands, the operation and maintenance of the USACE Willamette Basin Project is not likely to adversely affect the Aleutian Canada goose.

6.2.5 Bald Eagle

The primary prey for the nesting bald eagles of the project area are fish and waterfowl that depend on the aquatic resources in the Willamette Valley Projects. The bald eagle nest sites on project lands have been protected and managed to avoid and minimize harm to the species. The nest sites along the projects have established and successfully reproduced with the current level of human disturbance (i.e., recreational activities including fishing) at the projects. No changes in the nature and magnitude of human activities are anticipated at any of the 13 Willamette Basin projects. Disturbance could occasionally result to individual bald eagles, including those passing through the project area in winter or during migration. However, avoidance of human activities is more likely to occur. Consequently, the operation and maintenance of the Willamette Basin projects may affect but is not likely to adversely affect bald eagles. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.2.6 Northern Spotted Owl

Recreational and other human activities at USACE projects may potentially affect northern spotted owls. However, where spotted owl activity centers are known to occur, USACE lands are managed to protect the species by minimizing potential disturbance. Management objectives on lands that support the species include managing forests for natural succession toward old-growth state for the benefit of old-growth-dependent species including spotted owls. The operation and maintenance of the dams and other hydrological elements of the Willamette Basin projects would not affect spotted owls, as the species is not dependent upon, or require aquatic, wetland, or riparian habitats. Overall, the Willamette Basin projects operation and maintenance is not likely to adversely affect the northern spotted owl. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.2.7 Fender's Blue Butterfly

While Kincaid's lupine, the principle species on which the Fender's blue butterfly depends, is found at Fern Ridge, the USACE actively manages habitats at Fern Ridge Lake to preserve and protect the populations of Kincaid's lupine and other sensitive plant species. In addition, Kincaid's lupine is an upland plant that is not directly affected by the management of water levels in the Willamette Basin. Consequently, the operation and maintenance of the 13 Willamette Basin projects may affect Fender's blue butterfly, but is not likely to adversely affect the species. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.2.8 Canada Lynx

Although lynx have been detected in the project vicinity (nearest unconfirmed sighting was 2.5 miles from Cougar Dam), the Willamette Basin project lands do not offer suitable denning or foraging habitat for the species. In addition, the species is not dependent upon habitats affected by the management of flows in the Willamette Basin. Consequently, the action is not likely to adversely affect Canada lynx.

6.3 PLANTS

6.3.1 Golden Paintbrush

Potentially suitable habitat for golden paintbrush occurs on the east side of Fern Ridge Lake in the area where several listed, proposed, and candidate plant species have been identified and are being managed for their protection. However, the species has not been identified in surveys of this suitable habitat, and is considered extirpated in Oregon. This suitable habitat is not subject to activities that would affect its suitability to sustain existing and potential populations of these threatened and endangered plants. In addition, this species is not dependent upon wetland or aquatic habitats that are influenced by management of water levels at the projects. Consequently, the operation and maintenance of the Willamette Basin projects would have no effect to golden paintbrush.

6.3.2 Howellia

"Exceedingly wet or dry seasons can have a detrimental effect on plant numbers the following year" (59 FR 35864). Therefore, the operation of the Willamette Basin projects, in conjunction with the other Columbia Basin projects, by directly affecting water levels at Ridgefield National Wildlife Refuge, may potentially affect the remnant water howellia population at the site. Indirectly, the operation of the projects affects the success of other potentially competing plants (e.g., reed canarygrass). Excessive inundation may also introduce carp from the mainstem of the Columbia River into these ponds, with subsequent impacts to the success of water howellia and other wetland and aquatic vegetation. Consequently, the operation and maintenance of the Willamette Basin Projects is likely to adversely affect water howellia.

6.3.3 Bradshaw's Desert Parsley

The Recovery Plan for Bradshaw's desert parsley states that the USACE "has been exceptional in protecting their rare plant habitats" (USFWS 1993, p20). It notes, however, that fluctuations in hydrology may lead to invasion of reed canarygrass for those subpopulations near the edge of Fern Ridge Lake (USFWS 1993). It further adds that natural or induced modifications to the ponds, ditches, and other hydrologic structures, where other subpopulations are found, could affect the population (USFWS 1993). It is also noted that "the continued uses of the project area have the potential to modify rare plant habitats" (USFWS 1993, page 29). The USACE actively manages and protects the wet-prairie habitats are at Fern Ridge Lake to preserve the populations of Bradshaw's desert parsley and other sensitive plant species. Consequently, the operation and maintenance of the 13 Willamette Basin projects may affect Bradshaw's desert parsley, but is not likely to adversely affect the species. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.3.4 Nelson's Checker-mallow

While potentially suitable habitat for Nelson's checker-mallow may be present at Fern Ridge the species is not known to occur there. Consequently, the operation and maintenance of the 13 USACE Willamette Basin projects are not likely to adversely affect Nelson's checker-mallow.

6.3.5 Willamette Daisy

The population of Willamette Daisy at Fern Ridge Lake lies behind dikes at the East Coyote Unit and is not directly subject to hydrological impacts from the management of water levels in the reservoir. In addition, since the USACE actively manages and protects the wet-prairie habitats are Fern Ridge Lake to preserve the populations of Willamette daisy other sensitive plant species, the operation and maintenance of the 13 Willamette Basin projects may affect, but is not likely to adversely affect Willamette Daisy. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.3.6 Kincaid's Lupine

While Kincaid's lupine is found at Fern Ridge, the USACE actively manages habitats at Fern Ridge Lake to preserve and protect the populations of Kincaid's lupine and other sensitive plant species. In addition, Kincaid's lupine is an upland plant that is not directly affected by the management of water levels in the Willamette Basin. Consequently, the operation and maintenance of the 13 Willamette Basin projects may affect Kincaid's lupine, but is not likely to adversely affect the species. All activities outside the ordinary day-to-day activities at the projects are undertaken following separate Section 7 consultations with the USFWS.

6.4 SUMMARY OF EFFECTS

The Willamette Project consists of a large number of components that individually and collectively have had, and continue to have, numerous effects on ESA-listed species. Project facilities influence a large geographic area, and have done so for more than thirty years. This chapter has identified the most important effects of the Willamette Project.

6.4.1 Summary of Effects on Listed Fish Species

Tables 6-17 through 6-19 summarize the effects of the Willamette Project on listed spring chinook salmon, winter steelhead trout, and bull trout that occur above Willamette Falls. Blank entries in the table signify either "No Effect," or "Not Likely to Adversely Affect." In addition to effects addressed in two previous Biological Opinions (dated August 21, 1996 and September 26, 1997), the bank protection works associated with the Willamette Project are also "Likely to Adversely Affect" Oregon chub. The Willamette Project does not appear to have significant adverse effects on listed fish species that occur below Willamette Falls.

6.4.2 Summary of Effects on Listed Wildlife and Plant Species

Table 6-20 summarizes the results of the analysis of effects for wildlife and plant species. The Willamette Project is "Likely to Adversely Affect" only the plant species *Howellia aquatilis*.

Table 6-17. Summary matrix of the most likely current effects of the Willamette Project on the <u>Upper Willamette Chinook Salmon ESU</u>, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

Category / Physical Attribute/Activity / *Influence on Species/Critical Habitat*	Willamette Project Component										
	Detroit/ Big Cliff	Green Peter/ Foster	Blue River	Cougar	Fall Creek	Hills Creek	Lookout Point/ Dexter	Dorena	Cottage Grove	Fern Ridge	Bank Protection
Hydrograph Change and Water Quantity											
Flood Peaks											
Spawning Substrate Quality (fines)	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*		*PAA*				
Floodplain Processes	LAA	LAA	LAA	LAA	LAA		LAA				LAA
Large Woody Debris Recruitment	LAA	LAA	LAA	LAA	LAA		LAA				
Gravel/Cobble Recruitment and Transport	LAA	LAA	LAA	LAA	LAA		LAA				
Seasonal Flow Variability											
Smolt Migration Stimulation	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*		*PAA*				
Redd Stranding	LBA	LBA	LBA	LBA	LBA		LBA				
Rapid Flow Fluctuations											
Stranding/Trapping (Hydropower)	*PAA*			*PAA*							
Stranding/Trapping (Flood Control)	*PAA*	*PAA*	*PAA*	*PAA*	LAA		LAA				
Flow Augmentation											
Spawning Habitat Availability	LBA	LBA	LBA	LBA	LBA		LBA				
Rearing Habitat Availability	LBA	LBA	LBA	LBA	*PAA*		LBA				
Water Pollution	LBA	LBA	LBA	LBA	LBA	LBA	LBA				
Providing Passage to Fall Chinook at Will. Falls	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Water Quality											
Water Temperature											
Upstream Migration	LAA	LAA	LAA	LAA	LAA						
Fry Emergence	LAA	LAA	LAA	LAA	LAA		LAA				
Dissolved Gas	*PAA*	*PAA*	*PAA*	*PAA*			*PAA*				
Turbidity	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Fish Migration/Passage											
Upstream Migration/Passage											
Delayed Migration	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*		*PAA*				
Downstream Passage											
Delayed Smoltification				*PAA*	*PAA*						
Delayed Outmigration				*PAA*	*PAA*						
Other Habitat Changes and Losses											
Bank Stabilization & Channelization											
Habitat Complexity and Quality											LAA
Habitat Quantity											LAA
Floodplain Processes											LAA
Sedimentation (fine sediment budget)											
Floodplain Processes	LAA	LAA	LAA	LAA	LAA		LAA				LAA

Table 6-17. Summary matrix of the most likely current effects of the Willamette Project on the Upper Willamette Chinook Salmon ESU, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

Category / Physical Attribute/Activity / *Influence on Species/Critical Habitat*	Willamette Project Component										
	Detroit/ Big Cliff	Green Peter/ Foster	Blue River	Cougar	Fall Creek	Hills Creek	Lookout Point/ Dexter	Dorena	Cottage Grove	Fern Ridge	Bank Protection
Gravel Transport and Channel Morphology Change											
Gravel and Cobble Supply Interruption											
Spawning Habitat Quantity	LAA	LAA	LAA	LAA	LAA		LAA				
Channel Maintenance	LAA	LAA	LAA	LAA	LAA		LAA				
Large Woody Debris Supply	LAA	LAA	LAA	LAA	LAA		LAA				
Bank Erosion											
Cover & Habitat Capacity	*PAA*	*PAA*			*PAA*		*PAA*				
Fine Sediments	*PAA*	*PAA*			*PAA*		*PAA*				
Recreation and Fishing											
Water Quality		*PAA*					*PAA*				
Effects by Recreationers/Anglers	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*		*PAA*				
Predation, Exotics, and Community Species Shifts											
Predation		LAA			*PAA*		*PAA*	*PAA*	*PAA*	*PAA*	
Competition		LAA			*PAA*		*PAA*	*PAA*	*PAA*	*PAA*	
Hatchery Supplementation											
Population Maintenance	LBA	LBA	LBA	LBA	LBA		LBA				
Genetic Introgression/Interbreeding	LAA	LAA	LAA	LAA	LAA	LAA	LAA				
Genetic Fitness	LAA	LAA	LAA	LAA	LAA	LAA	LAA				
Predation/Competition	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Disease Transmission	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Injury/Disease in Trapping Facility		*PAA*			*PAA*		*PAA*				
Increased Fishing Pressure	LAA	LAA	LAA	LAA	LAA	LAA	LAA				

Table 6-18. Summary matrix of the most likely current effects of the Willamette Project on the Upper Willamette Steelhead ESU, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

Category / Physical Attribute/Activity / *Influence on Species/Critical Habitat*	Willamette Project Component										
	Detroit/ Big Cliff	Green Peter/ Foster	Blue River	Cougar	Fall Creek	Hills Creek	Lookout Point/ Dexter	Dorena	Cottage Grove	Fern Ridge	Bank Protection
Hydrograph Change and Water Quantity											
Flood Peaks											
Spawning Substrate Quality (fines)	*PAA*	*PAA*	*PAA*	*PAA*							
Floodplain Processes	LAA	LAA	LAA	LAA	LAA		LAA				LAA
Large Woody Debris Recruitment	LAA	LAA	LAA	LAA	LAA		LAA				
Gravel/Cobble Recruitment and Transport	LAA	LAA	LAA	LAA							
Seasonal Flow Variability											
Smolt Migration Stimulation	*PAA*	*PAA*									
Rapid Flow Fluctuations											
Stranding/Trapping (Hydropower)	*PAA*	*PAA*[1]									
Stranding/Trapping (Flood Control)	*PAA*	*PAA*									
Flow Augmentation											
Rearing Habitat Availability	LBA	LBA									
Water Pollution	LBA	LBA	LBA	LBA	LBA	LBA	LBA				
Providing Passage to Summer Steelhead at Will. Falls	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Water Quality											
Water Temperature											
Susceptibility to Disease	LAA	LAA									
Dissolved Gas	*PAA*	*PAA*									
Turbidity	*PAA*	*PAA*									
Fish Migration/Passage											
Upstream Migration/Passage											
Delayed Migration	*PAA*	*PAA*									
Transportation Stress		*PAA*									
Downstream Passage											
Delayed Smoltification	*PAA*[2]	*PAA*									
Delayed Outmigration	*PAA*[2]	LAA									
Regulator Intake/Turbine Injury & Mortality		LAA									
Spillway Injury & Mortality		LAA									
Predation Mortality		*PAA*									
Other Habitat Changes and Losses											
Bank Stabilization & Channelization											
Habitat Complexity and Quality											LAA
Habitat Quantity											LAA
Floodplain Processes											LAA
Sedimentation (fine sediment budget)											
Floodplain Processes	LAA	LAA									LAA

Table 6-18. Summary matrix of the most likely current effects of the Willamette Project on the Upper Willamette Steelhead ESU, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

Category / Physical Attribute/Activity / *Influence on Species/Critical Habitat*	Willamette Project Component										
	Detroit/ Big Cliff	Green Peter/ Foster	Blue River	Cougar	Fall Creek	Hills Creek	Lookout Point/ Dexter	Dorena	Cottage Grove	Fern Ridge	Bank Protection
Gravel Transport and Channel Morphology Change											
Gravel and Cobble Supply Interruption											
Spawning Habitat Quantity	*PAA*	*PAA*									
Channel Maintenance	LAA	LAA									
Large Woody Debris Supply	LAA	LAA									
Bank Erosion											
Cover & Habitat Capacity	*PAA*	*PAA*									
Fine Sediments	*PAA*	*PAA*									
Recreation and Fishing											
Reservoir Level Management[3]	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*	*PAA*				
Water Quality		*PAA*									
Effects by Recreationers/Anglers	*PAA*	*PAA*									
Predation, Exotics, and Community Species Shifts											
Predation		LAA			*PAA*		*PAA*	*PAA*	*PAA*	*PAA*	
Competition		LAA			*PAA*		*PAA*	*PAA*	*PAA*	*PAA*	
Hatchery Supplementation											
Population Maintenance	LBA	LBA			LBA		LBA				
Genetic Introgression/Interbreeding	LAA	LAA			LAA		LAA				
Genetic Fitness	LAA	LAA			LAA		LAA				
Predation/Competition	*PAA*	*PAA*			*PAA*		*PAA*				
Disease Transmission	*PAA*	*PAA*			*PAA*		*PAA*				
Injury in Trapping Facility		*PAA*[4]									
Increased Fishing Pressure	LAA	LAA			LAA		LAA				

[1] At Green Peter
[2] Related to water temperature
[3] Also for Flow Augmentation
[4] At Foster

Table 6-19. Summary matrix of the most likely current effects of the Willamette Project on the <u>Columbia River Bull Trout DPS</u>, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

Category / Physical Attribute/Activity / *Influence on Species/Critical Habitat*	Willamette Project Component: Detroit/ Big Cliff	Green Peter/ Foster	Blue River	Cougar	Fall Creek	Hills[1] Creek	Lookout Point/ Dexter	Dorena	Cottage Grove	Fern Ridge	Bank Protection
Hydrograph Change and Water Quantity											
Flood Peaks											
Floodplain Processes			*PAA*	LAA		*PAA*					
Large Woody Debris Recruitment			*PAA*	LAA		*PAA*					
Rapid Flow Fluctuations											
Stranding/Trapping (Hydropower)				*PAA*		*PAA*					
Stranding/Trapping (Flood Control)				*PAA*		*PAA*					
Flow Augmentation											
Rearing Habitat Availability			LBA	LBA							
Water Pollution			LBA	LBA							
Water Quality											
Water Temperature											
Habitat Suitability			LAA	LAA		*PAA*					
Dissolved Gas			*PAA*[2]	*PAA*		*PAA*					
Turbidity			*PAA*[2]	*PAA*		*PAA*					
Migration Barriers											
Migration Barrier											
Migration Corridors				LAA		*PAA*					
Spawning Habitat Availability				LAA		*PAA*					
Rearing Habitat Availability				LAA		*PAA*					
Fish Passage Stress and Survival											
Upstream Passage											
Delayed Migration				LAA		*PAA*					
Injury/Disease				*PAA*		*PAA*					
Downstream Passage											
Regulator Intake/Turbine Injury & Mortality				LAA		*PAA*					
Spillway Injury & Mortality				LAA		*PAA*					
Predation Mortality of Juveniles				*PAA*		*PAA*					
Gravel Transport and Channel Morphology Change											
Gravel and Cobble Supply Interruption											
Channel Maintenance			*PAA*	LAA		*PAA*					
Large Woody Debris Supply			*PAA*	LAA		*PAA*					
Bank Erosion											
Cover & Habitat Capacity				*PAA*		*PAA*					

Table 6-19. Summary matrix of the most likely current effects of the Willamette Project on the <u>Columbia River Bull Trout DPS</u>, with respect to baseline at the time of listing under the federal ESA (LBA = Likely to Beneficially Affect; LAA = Likely to Adversely Affect; *PAA* = Potential to Adversely Affect, but unconfirmed).

	Willamette Project Component										
Category **Physical Attribute/Activity** ***Influence on Species/Critical Habitat***	**Detroit/ Big Cliff**	**Green Peter/ Foster**	**Blue River**	**Cougar**	**Fall Creek**	**Hills Creek[1]**	**Lookout Point/ Dexter**	**Dorena**	**Cottage Grove**	**Fern Ridge**	**Bank Protection**
<u>Recreation and Fishing</u>											
Reservoir Level Management				*PAA*		*PAA*					
Effects by Recreationers/Anglers			*PAA*[2]	*PAA*		*PAA*					
Game Fish Stocking				*PAA*		*PAA*					
<u>Predation, Exotics, and Community Species Shifts</u>											
Predation				*PAA*		*PAA*					
Competition				*PAA*		*PAA*					

[1] Contingent on successful reintroduction.

[2] Based on limited, sporadic presence in Blue River below dam; other effects of Blue River Dam are with respect to mainstem McKenzie River.

Table 6-20. Summary of effects to listed and proposed endangered and threatened wildlife and plants.

Species	ESA Status[1]	Suitable Habitat Present or Suspected?	Species Present or Suspected?	Critical Habitat Present?[2]	Potential Effect?	Comments
Gray Wolf (*Canis lupus*)	LE	Yes	No	n/a	no effect	Species considered extirpated from Oregon since 1930. No confirmed sightings or suspected occurrences since that time.
Columbian White-tailed Deer (*Odocoileus virginianus leucurus*)	LE	Yes	No	n/a	not likely to adversely affect	Currently restricted to Douglas County. Potential to eventually occur, but unlikely at this time.
Marbled Murrelet (*Brachyramphus marmoratus*)	LT	No	No	No	no effect	No suitable nesting habitat within range of the species; most of project beyond range.
Aleutian Canada Goose (*Branta canadensis leucopareia*)	LT	Yes	Yes	n/a	not likely to adversely affect	Potential for only occasional occurrence at Fern Ridge.
Bald Eagle (*Haliaeetus leucocephalus*)	LT	Yes	Yes	n/a	not likely to adversely affect	Occur at most projects. Species monitored and protected.
Northern Spotted Owl (*Strix occidentalis*)	LT	Yes	Yes	Yes, adjacent	not likely to adversely affect	Occurs on adjacent lands at many projects. Species documented and protected.
Golden Paintbrush (*Castilleja levisecta*)	LT	Yes	No	n/a	no effect	Species extirpated. Potential habitat not affected by project operation.
Howellia (*Howellia aquatilis*)	LT	Yes	Yes (downstream)	n/a	**likely to adversely affect**	Three of the four individual colonies at Ridgefield National Wildlife Refuge are directly affected by the hydrology of the Columbia River downstream of the confluence with the Willamette River.
Bradshaw's Desert Parsley (*Lomatium bradshawii*)	LE	Yes	Yes	n/a	not likely to adversely affect	Occurs at Fern Ridge. Habitat indirectly affected by reservoir operation. Species monitored and protected.
Nelson's Checker-mallow (*Sidalcea nelsoniana*)	LT	Yes	No	n/a	not likely to adversely affect	Potential habitat present.
Willamette Daisy (*Erigeron decumbens* var. *decumbens*)	LE	Yes	Yes	n/a	not likely to adversely affect	Found at Fern Ridge. Habitat indirectly affected by reservoir operation. Species monitored and protected.

Table 6-20. Summary of effects to listed and proposed endangered and threatened wildlife and plants.

Species	ESA Status[1]	Suitable Habitat Present or Suspected?	Species Present or Suspected?	Critical Habitat Present?[2]	Potential Effect?	Comments
Kincaid's Lupine (*Lupinus sulphureus* var. *kincaidii*)	LT	Yes	Yes	n/a	not likely to adversely affect	Found at Fern Ridge at upland sites not directly affected by reservoir operation. Species monitored and protected.
Fender's Blue Butterfly (*Icaricia icarioides fenderi*)	LE	Yes	Yes	n/a	not likely to adversely affect	Found at Fern Ridge in association with Kincaid's lupine. Species monitored, documented, and protected
Canada Lynx (*Lynx canadensis*)	PT	Possibly	Yes in proximity	n/a	not likely to adversely affect	Occurs on lands surrounding several higher-elevation projects.

1 LE= Listed Endangered, LT = Listed Threatened, PT = Proposed Threatened, C = Candidate, SOC = Species of Concern

2 n/a = Critical habitat not designated for the species.